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SUGGESTED APPLICATION
OF CARTOGRAPHIC TECHNIQUES
TO TOPOGRAPHICAL MAPPING
IN LESS DEVELOPED AREAS

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SUGGESTED APPLICATION OF CARTOGRAPHIC TECHNIQUES
TO TOPOGRAPHICAL MAPPING IN LESS DEVELOPED AREAS

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INTRODUCTION

1. Despite the amount of literature on survey and mapping techniques, conferences similar to this one have been held at regular intervals on continental, regional and fully international levels. From this fact, one can deduce that representatives of the developing countries are seeking suggestions as to how they can best solve their problems.
2. The problems are primarily these:
 - (a) An inadequate or non-existent triangulation framework;
 - (b) Shortage of trained personnel;
 - (c) Urgency with which maps must be provided for development purposes.
3. In seeking a solution, resort is made to a study of what other countries are doing, only to find that the majority of them have a considerably greater national income, long-established cartographic organisations and have reached the present state of mapping over a period of several decades.
4. This paper suggests that it is not only vital to apply modern techniques, but also most important to have a definite stated policy so that available resources may be applied with concentration to meet the needs of the country.
5. It is recommended that this policy be implemented in three phases as follows:
 - (a) first phase: to provide for the minimum essentials;
 - (b) second phase: to provide for the further necessities;
 - (c) third phase: to provide for overall improvement.
6. It is also recommended that modern techniques be used in the prosecution of the various programmes.

GEODETIC SURVEY

7. It is generally acknowledged that a framework of permanently marked

stations, fixed in position and height on a national system, and a network of precise level bench marks are essential to serve as control for subsequent surveys and mapping, which latter, in turn, are essential for the planned development of the country. Wasteful unconnected surveys are eliminated where a national triangulation is in existence.

8. Primary triangulation sides average between 20 and 30 miles in length, which gives a density of about one point in every 500 square miles. This density is sufficient for 1/50,000 mapping when modern techniques are used. Secondary and tertiary triangulation, which provide the density of control required for larger scale mapping and for detailed surveys, are obtained by successive break-downs from the primary triangulation. Similar orders of precise levelling provide the framework of level bench marks.

9. It is recommended that the implementation of the policy in respect of the geodetic survey be

(a) first phase: to complete as soon as possible the primary triangulation and precise levelling over the whole country;

(b) second and third phases: to extend the secondary and tertiary triangulation and precise levelling. Circumstances may require that some secondary and tertiary triangulation and levelling be provided in selected areas during the first phase.

10. It will not be possible to delay a start on the mapping and other survey operations until the whole country has been covered by the primary triangulation, so the plan will have to recognise and provide for the fact that isolated control surveys may have to be performed and that the primary triangulation will have to be undertaken simultaneously in different sections situated in widely separated parts of the country. Isolated control surveys should be undertaken in such a way that they can be connected to or form part of, the main framework when it is extended into the region. The different primary nets should likewise be undertaken in such a way that they will form parts of the framework of primary triangulation of the whole country.

11. If geodetic chains have been completed, the primary triangulation can be proceeded with straight away but if not, the geodetic control for the primary triangulation will have to be provided first. It is desirable that the primary triangulation conform to the accepted standards of accuracy in order to form a solid basis for current needs and for the needs of the foreseeable future. Where the geodetic control is to be provided first, a decision will have to be taken, on the merits of each case, as to whether classical methods will be used, thus ensuring the accuracy of the subsequent primary triangulation, or whether use will be made of the less accurate but far more rapid method of trilateration using the "line crossing" method of measuring sides with electronic measuring devices. If this latter method is used, geodetic stations can be established from 150 to 250 miles apart, depending on the type of equipment used. For many countries, therefore, the geodetic "chain" would consist of a single polygon made up of a number of quadrilateral figures with an origin station roughly in the middle of the country. It may be advisable for this work to be undertaken on a contract basis by a concern equipped for and experienced in, such undertakings.

12. Whether the classical method of measuring the angles of the triangles by theodolite or whether the trilateration method of measuring the sides by means of measuring devices utilising either radio or light waves is used for the primary network, will have to be decided on the merits of each case. Each has advantages over the other in different sets of circumstances.

13. The combined cost of reconnaissance, observing and adjustment is about £300, £100 and £50 per station for the three orders of triangulation respectively, which constitutes a considerable investment of money, so the permanent marking of the triangulation stations is obvious. Since considerable use will be made of daylight observations directly onto the triangulation stations, distinctive opaque markers are essential. A 4 ft. high cylindrical concrete column with a removable sighting vane can be built over a centre mark in situ at an average cost of about £25. At least three witness marks must be placed and be measured to, so that the centre mark can be recovered accurately should the beacon be destroyed.

14. The precise levels should preferably be referred to mean sea level by direct connections to tide gauges or by connections to benchmarks in adjoining territories which are based on mean sea level. If this is not possible, a national datum must be chosen to which all levels and heights will refer. Permanent benchmarks should be placed every half-mile with a battery of three, one of which is considered as a fundamental benchmark, every 30 to 35 miles. Each section of the route must be levelled twice, i.e. in opposite directions. One leveller using a geodetic level with parallel plate and invar staves can average about 125 miles of such double levelling a year to primary levelling accuracy. Connections to triangulation beacons should be made wherever possible in order to increase the reliability of the trigonometrical heights. Automatic level instruments can be used for secondary and tertiary precise levelling.

AERIAL PHOTOGRAPHY

15. Aerial photographs are essential for modern mapping techniques. In addition, individual photographs and photo mosaics are planimetric topographical maps of a sort in themselves, which can be used for study purposes and from which much valuable information can be gleaned. Measurements, albeit of low accuracy, can be made on them. Relief can be studied from stereoscopic pairs viewed through a stereoscope. They are invaluable to geologists and many other scientists. Thus the provision of aerial photographic cover of the whole country is a high priority requirement in the first phase of the cartographic policy.

16. Some of the factors affecting the specification for the aerial photography are the following:

- (a) the scales of the maps to be produced from the photographs and the mapping techniques which will be used;
- (b) the value of the photographs as temporary planimetric maps;
- (c) the needs of the user, particularly regarding the scale of the photography;
- (d) the photographic cover is required quickly and economically;
- (e) priorities will necessitate the building up of eventual full cover of the country by way of isolated blocks of photography.

17. The 1/50,000 and 1/250,000 map series and the use of modern photogrammetric techniques are recommended in paragraph 21(a) for the first phase mapping programme. It is suggested, therefore, that the first phase aerial photography be

- (a) super wide-angle vertical photography to a scale of 1/70,000;

- (b) tilts not exceeding 2° ;
- (c) fore-and-aft overlap to be 80% and side-lap to be 25%;
- (d) photography to be in a series of rectangular blocks bounded by lines of latitude and longitude;
- (e) statoscope readings to be recorded for all photography.

18. It is appreciated that "dead" ground may result from super wide-angle photography in mountainous areas and that such photography is not really suitable for mosaicing. The plan, however, can be flexible enough to provide for special photography with another suitable camera in cases where such photography is absolutely necessary. It is appreciated also that the scale of 1/70,000 is somewhat large for 1/250,000 mapping but is suitable for 1/50,000. This scale is nevertheless recommended. The enormous advantages and savings which accrue from the use of super wide-angle photography make it the obvious choice.

19. The cost of aerial photography is dependent on the type of aircraft used, the disposition of airfields in relation to the areas to be photographed, the size and the grouping of the blocks to be photographed and on the scale of photography. Individual blocks of photography 6,000-8,000 square miles in extent, preferably covering a full 1/250,000 map sheet, are desirable. The cost of photography averages between 15/- and £1 per square mile in South Africa where Dakota aircraft are used, the aerodromes are within reasonable reach of the photo jobs and the blocks, although they tend to be on the small side, are usually conveniently grouped.

TOPOGRAPHICAL MAPPING

20. Countries with long-established survey and mapping organisations produce and maintain numerous map series on a wide variety of scales but it must be realised that this state of affairs has been built up over several decades and that it is quite impracticable for a developing country, starting virtually from scratch, to attempt to carry the same range. It is reasonable to set a similar objective as a long-term policy, but it is necessary to confine the first phase to absolute essentials.

21. It is recommended that the plan for the implementation of the policy regarding topographical mapping be:

(a) first phase: to cover the whole country as rapidly as possible with a 1/250,000 Topographical map series with 250 foot contours, running concurrently with but independently of, a 1/50,000 series with 50 foot contours. The 1/50,000 series in the first instance and until such time as the 1/250,000 series is completed, will be confined to the more developed areas and to those areas where it is known that early development will take place.

(b) second phase: the second phase will be implemented only when it will not jeopardise the early completion of the first phase. It will consist of the production of the 1/500,000 and 1/1M series by compilation from the 1/250,000 series, the progressive extension of the 1/50,000 series and the production of map series on a scale or scales larger than 1/50,000 in selected areas.

(c) third phase: the third phase will consist of the extension of the map series on scales of 1/50,000 and larger, the revision of existing maps as necessary, and of the expansion of the range of map series and special maps produced.

It will be noticed that the 1/250,000 map series is the smallest scale map which will be produced from de novo field work.

22. It is recommended that full use be made of the modern photogrammetric techniques of aerial triangulation and plotting of map manuscripts with the aid of stereoplotters. A battery of one first-order stereoplotter for aerial triangulation feeding five second-order stereoplotters for plotting, can complete between 6,500 and 7,500 square miles of 1/50,000 mapping per year, working one shift of normal office hours. Such a battery of six plotters represents a capital investment of about £35,000. Persons with a relatively high standard of education and an aptitude for the work are required as operators. Professionally qualified persons are required for the managerial posts. The advances made in electronic computers has renewed interest in the use of stereocomparators for aerial triangulation and much attention is being paid to this technique to-day, so the possible adoption of this method should receive consideration when the equipping of the photogrammetric section is being planned. The size of the photogrammetric section will depend on local circumstances regarding financial and manpower resources and on the mapping programme, besides which, a balance must be maintained between the production rates of the field survey and the photogrammetric plotting sections. For 1/50,000 mapping where the pencilled manuscript is inked-in by a tracer and not by the stereoplotter operator, the ratio can generally be taken as 1½ field units supplying field data and subsequently field-checking the manuscript, to one plotting unit working a single shift.

23. The pattern of photo ground control every 5 to 7 overlaps for aerial triangulation of strips for 1/50,000 mapping helps considerably in overcoming the difficulties of terrain and lack of access. This density can quite conceivably be reduced further if electronic computers are used for the adjustment of blocks of bridges. With this density, the photo ground control points can be fixed by triangulation, trilateration or by traverse employing electronic distance measuring devices from the primary triangulation framework. The heights of the ground control points can be determined by trigonometric levelling, spirit levelling or by properly controlled and executed barometric levelling using batteries of barometers.

24. It is recommended that the plotting of the map manuscripts from the aerial photographs be done to the scale and to the sheet lines of the published map. This plotting will be done in pencil and it is recommended further that the inking-in of the manuscripts be done by a woman tracer and not by the more highly skilled stereoplotter operator.

25. For various reasons which may include lack of capital and of suitable manpower, it may be difficult to establish and equip a section with stereoplotters and to staff it for some considerable time. As an interim measure to tide the organisation over this rather lengthy period of equipping the section and training the staff, resort may have to be made to some other method of map production. For this purpose the technique involving the slotted-templet for planimetric control, the contouring of spot-heighted photographs under a simple stereoscope and the plotting of the detail by means of a radial line plotter, can be considered. This method is applicable where there is a plentiful supply of manpower of a not very high standard of education because it lends itself to the distribution of the work amongst a number of people. The staff can be selected for their aptitude for performing one or other of the various operations and can be trained for and employed on that one operation only. The standard required of the field surveyor remains the same, whichever method is used. The density of the photo ground control and particularly of the spot heights for the contouring, requires

that virtually all the ground must be covered by the field surveyor, which is a drawback in difficult terrain. It requires also that plotting be done to a scale the same as or smaller than, that of the photographs, which would mean a review of the recommendation for the scale of aerial photography in paragraph 17(a). However, the method might be considered for the 1/250,000 mapping during the build-up period of the photogrammetric section.

26. The specifications for each map series, which are essential for any planned programme, can conveniently be divided into four interrelated parts covering details with respect to the following:

- (a) the topographical features which will be shown on the series;
- (b) the field survey operations and methods;
- (c) the procedure for plotting the manuscripts;
- (d) the manner in which the information will be shown on the published map, i.e. the specification for fairdrawing and printing.

LARGE SCALE ENGINEERING AND SPECIAL PLANS

27. This category of surveys does not fall within the scope of a paper on topographical mapping but brief mention must be made of such surveys and plans. The execution of such surveys should be the function of an organisation, or of organisations, other than that responsible for the geodetic survey and topographical mapping of the country.

28. The principle that subsequent surveys be connected to the national triangulation system applies equally well to this category. Since these surveys cover restricted areas for development purposes, it will be the duty of the geodetic survey to provide tertiary order triangulation in the areas of development, in order to make the connection of these surveys to the national system an economical proposition.

29. If suitable aerial photography is provided, modern photogrammetric methods can be used with advantage for large scale engineering plans.

FAIRDRAWING FOR MAP REPRODUCTION

30. The topographical information must be reproduced in a suitable form and in quantity so that it can be widely distributed. The reproduction of maps in quantity can best be done by the lithographic printing process, for which the map material has to be specially prepared. The map-user requires that the information be represented accurately and in such a way that the different topographical details can be distinguished readily. The use of different colours contributes to the ease of map interpretation. Colour separation fairdrawings are thus required as a step between the manuscript and the printing of the published map.

31. The three most common fairdrawing methods are:

- (a) drawing with pen and ink on an opaque medium;
- (b) drawing with pen and ink on a transparent medium;
- (c) scribing with cutting tools on a coated transparent medium.

It is essential that a stable medium be used for each method. Aluminium in-

terlined drawing paper is used for (a) and suitable plastics for (b) and (c).

32. It takes many months to train a draughtsman to the standard of craftsmanship required for pen-and-ink fairdrawings. On the other hand, it takes three to six weeks to train a person for the scribing method, for which a co-ordination between hand and eye, sufficient to follow a line accurately, is the only skill required. It has been the experience of all organisations that the rate of production increases with the changeover to the scribing method. The scribing method is thus recommended.

33. When map sheets are so urgently required that the delay in publication occasioned by the colour-separation fairdrawings cannot be tolerated, the manuscript itself can be reproduced in monochrome as a preliminary printed edition of the final map after the essential marginal information has been added by the draughtsman.

34. An experienced draughtsman should be able to complete the colour separation fairdrawings for 1,000 square miles of 1/50,000 mapping per year.

CONCLUSIONS

35. A national framework of triangulation and height control and a series of topographical maps are a prerequisite for the orderly and efficient development of a country. It is thus necessary to create an organisation to prosecute the geodetic survey and topographical mapping with energy.

36. The organisation must have a stated policy. It must be laid down that the policy is to be implemented in phases so that the minimum needs of the country are met in the order of their importance.

37. The suggested order is as follows:

(a) first phase: full cover of the country with primary triangulation and precise levelling, aerial photography and 1/250,000 topographical mapping; 1/50,000 mapping in selected areas;

(b) second phase: extension of the secondary and tertiary triangulation and precise levelling and of the 1/50,000 mapping; compilation from existing maps of the 1/500,000 and 1/1M series; production of maps to scales larger than 1/50,000 in selected areas; special photography; map revision.

(c) third phase: map revision and such further undertakings as required.

38. The phases will merge into each other at appropriate junctures. Where the need can be proved, operations from the next phase may have to be undertaken out of turn, but these must be restricted to the absolute minimum.

39. The bulk of the resources in the first instance must be allocated to the first phase geodetic and aerial photography programmes because they are prerequisites for the mapping undertakings. In the course of time, more and more of the resources will be directed to topographical mapping until eventually each undertaking will be allocated a share commensurate with its needs.

40. The application of the modern techniques which have been suggested will not only result in optimum production but will also reduce the adverse effects on the rate of production caused by difficult terrain. The use of

helicopters for the transportation of field survey parties will speed up the work considerably by still further overcoming the difficulties of terrain.

41. A methodical programme of staff training must be introduced in order to develop the skills and to raise the standard of education to the level demanded by modern techniques.



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MAPPING AND SURVEYING PRACTICES
ADAPTED TO USE IN LESS DEVELOPED AREAS

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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Paper A.1. Mapping and Surveying Practices
Adapted to Use in Less Developed Areas

by

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INTRODUCTION

1. In the short space available it is of course impossible to give more than a general outline of this very large subject; but in this paper an attempt has been made both to describe, with examples, the kind of maps and surveys required for the development of countries outside Europe; and also to outline the processes involved. Where possible an indication has been given of whether in the author's opinion particular tasks are better done by Government or commercial organisations; and some of the common pitfalls are also indicated. Two fundamental points have been stressed throughout. The first is that a progressive approach should be adopted, with a gradual localisation of the surveys at increasingly larger scales as the site of the proposed development becomes more closely defined. The second is that all surveys should be based on a sound and permanently marked framework which will form part of the permanent survey structure of the country. A great deal of public money has been wasted in the past by initiating surveys (particularly of communications) with too narrow an approach; and also by economising on the framework which has then had to be done all over again a few years later.

REQUIREMENTS

2. The general requirements for maps and surveys in planning and carrying out development projects are now so clearly understood that we can proceed directly to consider them in detail without having to justify them. They can be divided into four categories:- (i) Regional mapping (ii) Engineering surveys for specific projects (iii) Cadastral Surveys (iv) Natural Resources Surveys. Sharp boundaries cannot be drawn between these categories since there is always some overlapping. For example by far the greater part of the mapping done by this Directorate is at 1/50,000 scale which is on the boundary between regional and project surveys. Although the areas selected are usually dictated by the requirements of particular projects, we always ensure that the maps are on

proper national sheet lines and are drawn on a reasonably consistent specification. More important, if there is time for us to put in a fresh control framework, we insist that this should be permanently marked and surveyed to the standards required for a national framework and for eventual breakdown to a closer network for large scale mapping. In this way, whether a specific project is carried out or not, the mapping done for it becomes a substantial and permanent contribution to the map of the country and to its survey structure.

3. Regional Mapping Before the war few countries outside Europe had any comprehensive map cover at scales larger than $1/250,000$; but the extensive use of aerial survey has changed this. Large areas can now be covered rapidly at $1/100,000$ or $1/50,000$ scale especially if contours are not demanded in the first instance. The initial efforts of this Directorate in the immediate post war years were therefore concentrated on covering as wide an area as possible with what were called 'preliminary plots'. The majority of these were single colour planimetric maps (i.e. without contours), perhaps also temporarily deficient in names and other local information, but otherwise usually accurate and suitable not only for immediate use, but also as a base for subsequent editions. By 1956 over 300,000 square miles had been mapped in this way in Africa alone, and these so-called "preliminary plots" served an extremely useful purpose in making possible the initial consideration of some of the larger projects and in narrowing down the areas where development was feasible, and where contours etc. would be required in subsequent editions. It is interesting to note that in the Sudan a similar approach was followed, whereas in countries (such as Iraq or Jordan) where regional mapping was done by blocks on contract the mapping was contoured from the start, but the control framework was generally of a lower standard.

4. Engineering Surveys In this section we may consider maps on scales from $1/50,000$ to the largest scales at which maps are normally produced, i.e. about $1/500$. Most maps of this kind are contoured, with intervals varying from 30 metres to one metre or even less. Examples are given below of various types of projects.

5. Hydro-electric Schemes The requirements are normally threefold:- small scale maps for the catchment; a medium scale for the reservoir; and large scale maps of the areas where actual earthwork and detailed design are required, i.e. the dam itself, main canal headworks, power stations, and the associated residential and office sites. Access roads and transmission lines require preliminary medium scale maps followed by strip mapping at large scales. In the catchment area the other data required are rainfall and run off and these are so uncertain and variable that existing regional maps on $1/100,000$ or even smaller will therefore normally be adequate for any but very small schemes. The reservoir volume is required for estimating the amount of water held back by various heights of dam, and for this purpose a scale of $1/50,000$ or $1/25,000$ is usually adequate, with 5, 10 or 15 metre contours. There will be a requirement for a more accurate plan containing the limiting contour once this is known, with heights to within a metre or less. Evaporation, the effects of wind and pressure changes on the water surface, and the relatively unknown quantities of seepage and of silting will all affect the actual volume of water in the reservoir, and measured discharges into and out of it are also liable to errors of a few per cent. For selection of the dam site and the associated works the requirement is for maps on about $1/5,000$ scale but for detailed design of the

chosen site, the computation of quantities of material to be removed, and of concrete or rock fill to be put in, scales of 1/1,000 or so with contour intervals of a metre or less are by no means uncommon.

6. Towns and Settlements The mapping requirement for towns or other forms of settlement depends principally on whether the area is open or already built over. For the former a contoured map on about 1/2,500 with one or two metre contours is usually adequate, but for the latter it may be necessary to go to 1/500 scale and show spot heights along the streets. In both cases reference marks for future use can only be put in initially along the perimeter and on any main streets unlikely to be changed.

7. Irrigation Schemes The principal requirement for an irrigation scheme is naturally extreme accuracy in heights; and since the land to be irrigated must be reasonably flat, the contour interval required is likely to be of the order of five metres or less in the very preliminary stages, and of a metre or less when it comes to planning the detailed lay out. With the very small slopes (perhaps as low as one in 10,000) found in areas suitable for irrigation, contours take on a different significance since their positions on the map may be subject to very considerable errors - a centimetre or so at map scale - and a more precise way of showing the relief is to use spot heights at regular intervals, with the contours drawn between them to indicate, rather than to specify accurately, the shape of the ground. This kind of close control is slow and expensive; and every effort should be made by preliminary topographical and soil surveys to eliminate areas which are too high or have too poor soil to be usable.

8. Routes For these a progressive approach is particularly desirable. There should be a preliminary reconnaissance 'map' (it may be simply a mosaic of air photographs) of a wide strip from which progressively narrower areas are then selected for more detailed study and mapping at increasingly large scales and with closer contouring. Unfortunately design contracts seem often to be arranged in such a way as to confine the survey work to the large scale strip map required for the final design and quantities, without requiring enough preliminary surveys at smaller scales to make sure that the route followed is the best one. The result of this short sighted policy may well be that the actual construction of the road, railway, or transmission line (and also its future maintenance) will cost the Government concerned a good deal more than it need; and the extra cost may well be several times the money saved on the original surveys.

9. Cadastral Surveys These are required to define clearly and accurately the individual properties into which the land is divided, so that each land owner may feel secure enough to spend money or effort in developing his property. With physical and visible boundaries as in Europe the cadastral map reflects clearly the visible division of the land; but elsewhere parcels of land have to be defined by a series of straight lines joining corner beacons. Where the cultivation and ownership patterns differ, the production of a cadastral map is not as easy as it seems. It is therefore extremely important in a relatively undeveloped country not to introduce land registration without a full realisation of what is required to make it work. Without it people will settle their problems satisfactorily at village or family level; especially of course when there is no great pressure on the land. But once the Government has embarked on the registration of land parcels, usually including a guarantee of title, it

must make sure that these can be properly identified and defined; and this can only be done by a cadastral survey of sufficient accuracy to meet the particular circumstances. This century can show far too many examples of a Government which has started a system based on sketch maps or even on no surveys at all; only to find itself after a few years quite unable to keep pace with or control the flood of worthless paper which has resulted; to keep track of changes of ownership, subdivision or amalgamation of parcels; or to settle the endless disputes over boundaries and ownership for whose settlement it has now become responsible.

10. The general purposes of cadastral surveys are therefore four:- (i) To define, locate, and index all parcels of land (ii) To restore at any time a disputed boundary (iii) To determine the areas of parcels for fiscal or economic purposes (iv) To keep a continuous and up to date record of the subdivision or amalgamation of the parcels as may be required on sale or inheritance or for such purposes as building development or consolidation for better farming methods. It is not possible here to expand on these individually, but three points may be noted:- First: uncertain boundaries, especially where pressure on the land is heavy, are a fruitful source of dispute; and proper survey records of the original boundary are indubitably the most satisfactory evidence for settling them when the survey is supported by permanent reference marks. Hedges, particularly in the tropics, may spread or grow in the wrong place or fail to grow at all; fences, walls, and corner beacons can be moved; but a boundary line or beacon whose original survey was connected to the properly marked control framework of the country can always be restored by reference to this, and any changes can be surveyed without any deterioration in accuracy. Secondly: the requirement for accurate areas means that the map must be properly surveyed and scaled; but areas should not be quoted too precisely or they may be found to conflict with the boundaries in defining the extent of each parcel. Finally, one must remember that a cadastral survey is a continuous process and that it must be kept up to date. The need for maintenance staff is the strongest argument for not having the whole initial survey done by an outside contract, since this does not leave behind staff who have taken part in the initial survey and have thereby received the training, interest, and pride in the structure which it will their duty thereafter to maintain.

12. Natural Resources Surveys Different climates have different potentialities and different soils have distinct management requirements. Over the centuries farmers learned to cope with these differences and characteristic systems of agriculture were developed in the various parts of the world. Now agricultural research, the production of artificial fertilizers, and mechanization have revolutionised agriculture in the temperate regions, and subsistence agriculture is giving way to cash cropping in the tropics. The cry of the less developed areas is for more food and increased production of export crops. How can this be achieved? The tropics are so different in their soils as well as their climates that farming techniques developed in the temperate regions cannot be introduced wholesale. Surveys and experimentation are needed to answer the following questions: How should a certain area be used? What crops should be produced? Could it be grazed, if so at what frequency and density? Does it contain exploitable timber? Is it being used to capacity already? In general, surveys are needed to provide geographical information on the natural resources and to supply the link between research worker and farmer. Outstanding results have been achieved on experimental farms in the tropics, but all too often these results have not led to increased yields over large areas owing to lack of survey

data. Experimental findings are only relevant to areas of similar soil and climate, and without maps and surveys it is impossible to know where those areas are or how extensive they are.

13. Surveys for agricultural and forestry development fall into three groups. First are surveys of directly exploitable resources: forest inventories including type mapping, location of economic species and calculation of volumes; pasture surveys comprising the mapping and analysis of the main communities, observation of seasonal changes and the assessment of livestock carrying capacity; and surveys of other economic species - e.g. the Shea Butternut Tree or gum-producing trees. The second group contains surveys of the agricultural environment: ecological and soil surveys to assess the suitability of land for different purposes and to provide a geographical framework for the findings of experimental stations. The third group comprises surveys of current land use: surveys of the mode and density of land use and the effect this use has on the land.

SURVEY AND MAPPING PROCESSES

14. Mapping can be broken down into the following six main steps: (i) The Basic Framework (ii) Aerial Photography (iii) The breakdown of the main framework into minor control (iv) Detail mapping (v) Ground Completion (vi) Fair drawing and printing. The compilation of special maps to show natural resources follows a different process and is described separately.

15. The Basic Framework, or Geodetic Survey The framework of any survey plays rather the same part in it as the steel framework of a modern building: it is essential for strength and for later repairs and modifications to the walls; but for most of the building's life it remains hidden and often forgotten. In mapping, an accurate framework is required to ensure a uniform scale and that there shall be no overlaps or gaps between the mapping of adjacent areas. The framework may be formed of points fixed in plan by astronomical observations, radar distances, triangulation, or traverse, or by a combination of these; and heights may be obtained by spirit levelling or by vertical angles between the triangulation or traverse points, but the first two methods by themselves are only of value in the very preliminary stages of mapping a country, although they are of great use in combination with the other methods.

16. Until a few years ago triangulation was used for all major frameworks, except occasionally in countries such as Nigeria and Ghana where low relief and thick forest made it necessary to rely on precise taped traverses along the roads and railways. Now that distances up to 40 miles or more can be measured electronically with great accuracy and speed, most frameworks are being built up by a combination of distance and angle measurement that falls somewhere between triangulation and traverse. The speed of working is now very great; for example this Directorate ran a precise Tellurometer traverse of 600 kilometres in Kenya in 1957 in one month; a task which by other means would have taken at least two seasons; and in Sarawak recently one of our surveyors established 53 points covering a distance of nearly 500 kilometres in five and a half months through thickly forested country.

There is a temptation in the rush for development to be content with a basic framework of a standard adequate only for the immediate purpose; but it must be

realised that a sound geodetic framework, accurately surveyed and permanently marked (preferably by concrete pillars) is the best survey asset any country can have; and it has been the policy of this Directorate to concentrate its field staff on doing this, and to provide temporary and less accurate work only when there is no time to do otherwise. This work does not lend itself readily to being done by contract because its very nature demands a permanent staff of highly qualified surveyors working to close specifications, without being pressed to cut corners or meet contract dates.

17. The provision of a basic framework of accurate heights is generally an easier proposition than the planimetric control since even the most precise levelling is a relatively straight-forward process which can be carried out by less highly trained surveyors under supervision, especially since the level lines can follow established lines of communication. Heights can be carried along the plan framework by observing vertical angles; but this is a good deal less accurate. Here again permanent marking of the level bench-marks is essential and as many as possible should be sunk in rock. Barometric heighting is not accurate enough for the basic framework.

18. Aerial Photography The greater part of topographical mapping is now done from aerial photographs, most of them taken with the camera axis vertical. The exposure interval is adjusted so that along each strip there is a forward overlap of about 60%, and adjacent strips overlap laterally by about 25%. Thus every part of the ground is covered by at least two photographs and can be viewed stereoscopically. This makes possible the appreciation of relief and thus the drawing of contours; and it also greatly increases the possibility of interpreting the photographs correctly, since the actual shapes and heights of objects can be appreciated and detached from their shadows. Photographs can now be taken at very small scales from great heights, but this limits their usefulness for interpretation and even for topographical mapping since small villages, tracks, and even minor railways cannot be seen. Oblique photographs are now scarcely used. The taking of vertical photographs is a highly skilled process, especially in areas where the maps are inaccurate. Navigation can be either radar controlled, as in the early days of British Royal Air Force photography overseas, or visual using various techniques. It is essential in any extensive photographic task to set up a processing laboratory within reach of the aerodrome from which the aircraft is operating, in order to provide rough prints which are used in the air for navigation, to keep a daily check on the cover completed, and to ensure that correct exposures are used.

19. Several newly independent countries have set up their own organisations for aerial photography, usually in conjunction with their local air line or air force. While this may be effective and economical for either very small areas such as individual towns, or for very extensive preliminary coverage at small scales, it seldom results in a standard of either navigation or photography which can compare with results obtained by the specialist commercial air survey companies. The result is that the best and most economical use cannot be made of the photography and it often has to be repeated when accurate mapping is required.

20. Minor Control Until the last few years the basic framework of points already described, which are as a rule twenty or more kilometres apart, had to be broken down by similar methods of ground triangulation or traverse into a close network of minor control points within which the detail survey could be carried

out by relatively simple methods, either on the ground or from air photographs. But the use of more stable film, more refined stereoscopic measuring and plotting machines, and modern computers have made it possible to achieve astonishing accuracies by aero-triangulation using the geometrical properties of the air photographs. In some cases these accuracies exceed one part in twenty thousand in plan and are therefore as good as second order frameworks surveyed on the ground. The stage has now been reached that for many mapping tasks, particularly at medium scales, the survey plan control put on the ground can be relatively widely spaced at intervals covering several photographs, with the network of minor control between provided entirely by the photography. This is less true of heights; and where close contouring is required, as at larger scales than 1/50,000 or for irrigation schemes, then the basic framework of precise levelling has to be broken down by a network of minor level lines. For more rugged country heights may be measured by barometer. As far as possible a proportion at least of these minor control points should be marked on the ground, since they will then form an invaluable local datum on which larger scale surveys for specific projects, or for setting out of actual construction works, can be based.

21. Detail Mapping It is in detail mapping that air photographs have really taken over; detailed surveys on the ground are now usually restricted to regions where weather or forest cover prevent air photography and to small areas for which photography would be uneconomical. Even cadastral surveys, particularly where the boundaries are visible from the air, can now often be done from air photographs. Once we have obtained, either by ground survey or by aerotriangulation, the positions and heights of at least three points on every overlapping pair of photographs, each pair can then be put in a stereoscopic plotting machine and the resulting three-dimensional model can be correctly scaled and levelled. All topographical features in this model can be plotted as detail or contours, and so piece by piece the map as a whole is built up, the basic and minor control frameworks ensuring that each piece will fit exactly into its proper place, regardless of the order in which it is put together or of how many different machines and operators are used.

22. In the plotting machines the two photographs are either projected down in complementary colours onto a table and viewed by the operator with coloured spectacles; or the three-dimensional problem is solved mechanically, the operator viewing the image through binoculars and moving a small dot in the field of view over the surface of the model to trace out features and contours. With the most refined and expensive instruments the plotting scale can be up to eight times that of the photographs; and with good photography and frequent height control contours can be plotted with an interval as small as 0.05% of the height above ground from which the photographs were taken. It is using a smaller scale of photography and consequently fewer photographs and less ground control which pays for the more expensive instruments; but these require a higher degree of sophistication and experience in their operation. An aerial survey unit in a less developed country should therefore rely initially on simpler methods and equipment until the required degree of experience is reached for the more advanced instruments. Too many of these are not being used because of the lack of trained operators; while under more realistic arrangements elsewhere very effective maps are being turned out at less cost by less sophisticated methods.

23. Ground Completion With the virtual replacement of ground survey of detail by air survey, the collection of local information such as the classification of

roads and the collection of names has become a separate process; and this is normally carried out on photographic copies of the photogrammetric plot before the latter is fair drawn. The best agency for ground completion is the local survey department; but a proper specification has to be drawn up for the various classes into which roads and similar details may fall, with definitions in sufficient detail to ensure that the field classifiers do their work uniformly.

25. Fair Drawing and Printing The accurate document produced by the photogrammetrist or field surveyor then has to be fair drawn and separated into as many colours as are required on the final map. This is nowadays done on special plastic sheets with names printed separately and added to them; and the lithographic printing plates are made from these. The smaller Survey departments tend either to have their printing done elsewhere or to undertake other government printing as well to keep their machines fully occupied.

26. Compilation of Special Maps to show Natural Resources The methods used to compile natural resources maps are as various as the different kinds of survey. There are few surveys however, in which aerial photographs are not of the greatest value, and they are particularly valuable in natural resources surveys since they present a detailed picture in which the interrelated patterns of soils and vegetation, rock types, landscapes and drainage, land use and settlement can be observed separately or in combination. The print laydown (uncontrolled mosaic) is another important tool which is particularly useful for breaking down large tracts into manageable units by establishing the main distributions of the landscape and vegetation types, and as a base for recording the findings of special surveys in areas that lack adequate topographic maps. A stylised programme for land use development surveys would include the following stages: (i) Compilation and correlation of the existing data. (ii) Aerial photograph interpretation to produce a type map. (iii) Studies on the ground to check the aerial photograph interpretation and to analyse the different units. (iv) Production of report and field-revised maps.

27. The programme could often be improved by two additional stages between (i) and (ii), viz, a preliminary examination of the aerial photographs, and a short period of field work to establish standards for the full aerial photograph interpretation. Time and cost generally preclude these additional stages. Occasionally a special programme of field work is not essential, e.g. when an area is well documented or when only a simple break-down of types is required. Other surveys - notably pasture surveys - rely more on field work than aerial photograph interpretation, but may use a print laydown to record their results. Where adequate topographic maps on regular sheet lines are available, or can readily be made from the air photographs, they would normally be used as a base on which to overprint the special information relating to natural resources, perhaps after the deletion of some topographic information or the special printing of topographic information in a neutral colour such as grey.



**CONFÉRENCE DES NATIONS UNIES
SUR L'APPLICATION DE LA SCIENCE ET DE LA TECHNIQUE
DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES**

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Viet-Nam

RESSOURCES ENERGETIQUES

Par DINH QUANG CHIEU
Directeur général de l'Electricité du Viet-Nam

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

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Conférence des Nations Unies sur l'application de la Science
et de la Technique dans l'intérêt des régions peu
développées : REPUBLIQUE du VIETNAM :

N°285 A 4. RESSOURCES ENERGETIQUES

par

DINH QUANG CHIÊU

Directeur général de l'Electricité du VietNam

I. a/ Comme la plupart des pays en voie de développement, le Vietnam a été, jusqu'à la deuxième guerre mondiale, un pays traditionnellement fournisseur de produits primaires, principalement agricoles. Il existait cependant quelques petites industries de transformation travaillant surtout pour la consommation intérieure, et accessoirement pour l'exportation vers les pays voisins.

b/ Ce n'est qu'à partir de 1955 que la poussée vers l'industrialisation est devenue plus soutenue, les investissements industriels se maintenant à un rythme annuel de l'ordre de 500 millions de piastres vietnamiennes équivalentes à 60 millions de US\$ par an.

Cet effort continu dans le développement industriel implique la mobilisation de toutes les ressources naturelles utilisables parmi lesquelles les plus importantes sont les ressources hydrauliques et énergétiques.

Les ressources hydrauliques du Vietnam font l'objet d'un autre mémoire; signalons cependant que la richesse énergétique de l'ensemble des bassins du pays serait de 49 milliards de Kwh par an, dont, 8 milliards de Kwh pour les bassins déjà explorés. Des aménagements pour l'hydraulique agricole absorberont une partie notable de ces ressources.

Des réalisations et projets en cours, en vue de la production d'énergie hydroélectrique, citons :

- l'équipement du Danhim fournissant 160.000 Kw
première tranche 80.000 Kw (extension possible à 400.000 Kw)
terminée en 1963
deuxième tranche 80.000 Kw
terminée en 1965
- l'équipement de TriAn,
(sur le Donai) 100.000 Kw
projet en cours d'étude
- l'équipement du ThuBon près de
la mine de NongSon 200.000 Kw
(projet à l'étude)

Le recensement systématique et l'utilisation rationnelle de ses ressources énergétiques dans le cadre du développement général est une tâche à laquelle s'adonne ce pays depuis le démarrage de son premier plan quinquennal (1957-1961); en dehors des ressources hydrauliques relativement abondantes, le Viet-Nam, dans l'état actuel des prospections, ne dispose que d'une quantité limitée de combustibles classiques (charbon). Quant aux ressources non classiques d'énergie, leur utilisation ne semble pouvoir s'imposer que dans des cas très particuliers.

II.

a/ Charbon. La mine de NongSon, dans la province de Quang-Nam, a une réserve estimée pour le moment à 3 millions de tonnes d'anthracite. Ce chiffre doit être considéré comme un minimum car des recherches en cours laissent espérer des réserves beaucoup plus importantes. Ce gisement est formé de couches d'anthracite allant de 1 mètre à 30 mètres d'épaisseur. La production annuelle sera de l'ordre de 250.000 tonnes dont 40.000 tonnes environ seront utilisées en dehors de la région de Nong Son, pour la production d'énergie électrique et des consommations diverses ; le reste de la production sera absorbé par le complexe industriel de AnHoa près de la mine de NongSon : production d'énergie électrique pour le complexe et les besoins extérieurs (25.000 Kw) gazéification de l'anthracite, liquéfaction de l'air, fractionnement de l'air

liquide, synthèse de l'ammoniac, fabrication de l'urée et du sulfate d'ammonium, fabrication d'acide sulfurique, de carbure de Calcium, de matières plastiques.

L'utilisation de cet anthracite à proximité de la mine est la plus économique.

b/ Combustibles pétroliers.

Les besoins en combustibles pétroliers s'établissent aux environs de 4.800.000 barils en 1962 et 5.300000 barils pour 1968 et se répartissent comme suit : (en baril : 159 litres)

	<u>1962</u>	<u>1968</u>
Essence aviation	115.000	71.000
Combustible pour turbine (aviation)	58.000	157.000
Essence	1.649.000	1.736.000
Kérosène	715.000	1.288.000
Diesel fuels	1.267.000	1.456.000
Fuel oil	1.016.000	537.000

(la diminution de la consommation en fuel oil est due au remplacement graduel de l'énergie thermique par l'énergie hydroélectrique entre 1962 et 1968)

Actuellement les produits pétroliers sont tous importés. Une raffinerie est en cours de réalisation, pour fonctionner, à partir de 1965 : elle traitera 22.000 barils de brut importé par jour (extension possible jusqu' à 30.000 barils / jour). Sa production couvrira tous les besoins, à l'exception de quelques produits spéciaux.

En ce qui concerne le pétrole brut, les quelques données très sommaires dont nous disposons actuellement ne permettent pas d'établir une opinion sur la probabilité de succès d'un programme éventuel de recherche de gisement. Pour un temps indéterminé le pays dépendra donc de l'extérieur quant à l'approvisionnement en pétrole brut.

c/ Autres combustibles solides.

Il convient de mentionner l'existence, au Sud, d'une région tourbeuse d'une superficie exploitable de plus de 100.000 hectares. La grande teneur d'humidité de cette tourbe, l'éloignement de cette région des cen-

tres d'utilisation possible, posent des problèmes techniques et économiques tels que jusqu'à présent aucun projet d'exploitation n'a été abordé.

D'autre part, suivant l'opinion de quelques experts, une extraction imprudente de cette tourbe pourrait amener l'envahissement de cette région côtière par de l'eau salée.

d/ Sources non classiques d'énergie.

i) Energie éolienne.

La vitesse moyenne du vent dans les régions du Sud est de l'ordre de 2 à 4 m/s avec des pointes de 10 à 12 m/s tandis que dans les régions du Centre, cette moyenne est plus élevée : 3 à 6 m/s avec des pointes dépassant 20 m/s. Il semble donc que les régions du Centre offrent plus de possibilités quant à la captation de l'énergie éolienne. Les données météorologiques précédentes ne peuvent évidemment servir qu'à indiquer les régions dans lesquelles il conviendrait de procéder aux explorations systématiques des sites avec des appareils et instruments appropriés. Quelques études ont bien été tentées dans le Sud, vers 1949, avec des compteurs-enregistreurs d'énergie mais elles n'ont pas été poursuivies, les résultats des quelques relevés effectués n'ayant pas paru assez encourageants. Nous nous garderons cependant d'une conclusion hâtive, l'étendue des études n'ayant pas été suffisante. Il nous faudrait les reprendre sur de nouvelles bases, plus systématiques, utilisant l'expérience acquise dans d'autres pays dans ce domaine et pousser les recherches dans les zones plus intéressantes du Centre VietNam.

L'énergie éolienne sera utilisée, pour commencer, dans l'électrification rurale et l'irrigation de petits domaines; ensuite, dans des stations plus importantes, isolées ou connectées aux réseaux électriques locaux.

ii) Energie solaire.

La transformation directe de l'énergie solaire en énergie électrique exige des investissements importants, le prix des cellules étant encore trop élevé; aussi il est normal qu'en dehors de cas très particuliers, ce procédé de captation de l'énergie solaire ne soit pas encore

d'un emploi répandu dans les pays en voie de développement. Il en est autrement quand cette énergie est utilisée à des usages ménagers ou pour la distillation de l'eau salée dans quelques régions côtières de ce pays dépourvus d'eau douce durant plus de la moitié de l'année; il s'agit de trouver, là encore, des appareils simples et d'un prix modeste les mettant à la portée des usagers à faibles moyens.

iii) Energie nucléaire.

Dans l'état actuel des choses, l'installation d'une ou de plusieurs centrales nucléaires en vue de la production d'énergie électrique ne s'impose pas au Viet-Nam, tant que les ressources classiques du pays dont l'exploitation est actuellement plus économique ne sont pas toutes utilisées.

Une centrale expérimentale à faible puissance serait cependant utile pour des essais et recherches et pour la formation sur place de techniciens.

III. Energie électrique.

a/ Besoins.

Dans la région de Saigon, qui est la plus industrialisée, la croissance de la demande en énergie électrique s'établit entre 10% et 12% par an jusqu'à 1972; ensuite elle reprendra la valeur normale de 8 à 9% par an.

Dans les provinces, cette croissance est estimée à 7% par an. Il est à noter qu'à partir de 1964, les industries qui, actuellement produisent elles-mêmes l'énergie dont elles ont besoin, seront connectées au réseau public (leurs centrales restant alors en secours); d'où un transfert graduel de 30.000 Kw sur le réseau public. Le tableau ci-dessous donne les prévisions de la demande normale, de 1962 à 1972, pour l'ensemble du Viet-Nam :
(Réseau public + centrales privées)

	<u>Pointe : en Kw</u>	<u>Consommation : en 10⁶ Kw</u>
1962	106.000	550
1964	121.000	695
1966	165.000	920
(y compris 25.000 Kw : Complexe chimique d'AnHua-NongSon)		

1968	195.000	1.090
1970	233.000	1.320
1972	283.000	1.560

b/ Production.

Dans la région de Saigon, la production est assurée actuellement par :

une centrale à vapeur	52.000 Kw installés
3 Centrales Diesel	34.000 Kw
Groupes privés	40.000 Kw

En province :

deux centrales hydroélectriques :	4.000 Kw installés
Total des centrales Diesel	: 20.000 Kw

En 1963 (Octobre) la première tranche du projet hydroélectrique du Danhim apportera 80.000 Kw et en 1965 la deuxième tranche fournira 80.000 Kw.

Citons encore :

En 1964 une nouvelle centrale thermique près de Saigon qui fournira 33.000 Kw et en 1965, la centrale déjà citée d'AnHoa-NongSon de 25.000 Kw qui fournira de l'énergie au complexe chimique de même nom ainsi qu'aux régions environnantes (port de Tourane).

Trois projets hydroélectriques (TriAn sur le Donai, au Sud; ThuBon au Centre VietNam et aménagement du Lagna au Sud) sont en cours d'étude et leur réalisation probablement dans l'ordre indiqué permettra de disposer d'un apport supplémentaire de :

100.000 Kw vers	1968 (TriAn)
+ 200.000 Kw vers	1970 (ThuBon)
+ 100.000 Kw vers	1972 (Lagna)

Comme puissance installée de production, le pays disposera donc de :

1962		150.000 Kw
1964	150.000 + 33.000 + 80.000	: 263.000 Kw
1966	263.000 + 80.000 + 25.000	: 368.000 Kw
1968	368.000 + 100.000	: 468.000 Kw

1970	468.000 + 200.000	:	668.000 Kw
1972	668.000 + 100.000	:	768.000 Kw

Il est permis d'espérer qu'à partir de 1972, un apport très important viendra de l'extérieur, à la suite des aménagements sur le bassin du MéKong.

c/ Les deux plus grands centres de consommation sont : la région de Saigon avec sa zone de développement industriel (au Nord Est de Saigon) et la région industrielle d'AnHoa-NongSon près de la mine d'anthracite de NongSon. Ces deux centres ne seront pas interconnectés avant la réalisation des grands projets hydroélectriques de TriAn au Sud et du ThuBon au Centre, vers 1970. Dans chacune de ces deux zones, et par la suite, après l'interconnexion, on cherchera à exploiter ces différentes sources d'énergie dans les conditions les plus économiques en considérant non seulement le côté technique des opérations mais aussi les facteurs déterminants du prix de revient du kilowatt-heure produit lequel est lui-même un élément important de l'économie générale du pays.

IV. Le VietNam ne manque pas de ressources énergétiques. Venu tout récemment à l'industrialisation, il a besoin de mobiliser sans retard ces ressources pour faire face aux besoins industriels qui augmentent rapidement. Cependant l'établissement des projets se trouve freiné par l'absence souvent constatée de données de base qui ne peuvent se recueillir qu'à la suite de relevés effectués pendant de nombreuses années. La science et la technique modernes peuvent intervenir pour éviter une attente trop longue par l'emploi de méthodes ou de procédés plus expéditifs (mais aussi sûrs) permettant l'élaboration des projets avec les quelques données existantes à compléter au besoin par d'autres, qu'il faudra rapidement acquérir.

L'aide de la science et de la technique sera également précieuse dans l'adaptation nécessaire des équipements et matériels au niveau d'industrialisation et aux conditions climatiques des pays peu développés, dans l'amélioration des conditions de travail et enfin dans la formation accélérée des techniciens locaux.

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Belgique

APPLICATION DES METHODES MODERNES
DE PROSPECTION GEOLOGIQUE ET GEOPHYSIQUE
A LA RECONNAISSANCE D'UN VASTE BASSIN SEDIMENTAIRE
EN AFRIQUE CENTRALE

Par Pierre EVRARD,
Professeur à l'Université de Liège(Belgique),
Membre associé de l'Académie Royale
des Sciences d'Outre-Mer

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1. INTRODUCTION

On pourrait croire que la mise au point, au cours des vingt dernières années de méthodes d'investigations géologique et géophysique rapides, tels les levés photogéologiques, magnétométriques et électriques aériens rendent facile et peu coûteuse la reconnaissance de vastes régions du globe, encore inconnues.

Ce serait considérer les problèmes d'une manière trop simpliste que d'imaginer que la mise en oeuvre de ces moyens modernes peut se faire suivant un schéma qui s'appliquerait d'une manière invariable aux régions les plus différentes.

Les réflexions qui suivent résultent de l'expérience acquise au cours de la conduite de travaux géologiques, géophysiques et de sondages entrepris dans le bassin central du Congo (République du Congo - Léopoldville).

Les conclusions pratiques tirées de ce cas particulier quant aux aspects administratif, technique et financier d'une telle entreprise, peuvent avoir une portée générale.

2. BASES JURIDIQUES

L'inventaire géologique et minier est en fait un devoir de souveraineté de l'Etat. Dans le cas particulier de la cuvette congolaise, une solution originale a été appliquée. Elle a consisté en la création, en 1951, du "Syndicat pour l'étude géologique et minière de la Cuvette congolaise". Dans cet organisme, l'Etat (à l'époque le Congo Belge) s'est réservé 40 % du capital; les 60 % restants ont été souscrits par 34 personnes et entreprises privées.

Un décret gouvernemental a accordé au Syndicat, en contrepartie des risques financiers assumés par des capitaux privés, un droit exclusif de recherches portant sur les substances fossiles combustibles ou bitumineuses et sur celles exploitables par suite de leur teneur en soufre ou en phosphore.

Le décret a fixé aussi les droits et obligations du Syndicat: durée de la

convention, conditions pour son renouvellement, réduction progressive des surfaces concédées, obligation minimum de dépenses par période, etc.

L'association de l'Etat et de privés pour la réalisation d'un tel projet présente un caractère d'originalité qu'il convient de souligner. La gestion d'un tel organisme sur une base industrielle a présenté plus de souplesse que si elle avait été assurée dans un cadre administratif parfois soumis à des règles trop rigides. La qualité scientifique des résultats obtenus a cependant été tout autant assurée. L'Etat, malgré sa participation minoritaire a conservé un droit de veto sur toute décision qui aurait lésé l'intérêt général du pays.

Il faut faire remarquer que le succès d'entreprises de cette importance, disposant des moyens scientifiques et techniques les plus modernes et de personnel hautement qualifié, repose en grande partie sur une liberté d'action assurée par un statut juridique approprié.

3. ENONCE DU PROBLEME

En 1952, lorsque les premières recherches du Syndicat ont débuté, la géologie de la Cuvette était mal connue. On n'avait que des informations fragmentaires concernant sa périphérie. Les régions centrales étaient d'accès difficile: couvertes de forêts tropicales et de marécages, parcourues par quelques routes seulement.

La nature, l'âge, l'allure, l'épaisseur des formations géologiques que l'on supposait s'être accumulées au moins depuis le Permien dans cette immense dépression (environ 1.000 km de diamètre et 800.000 km² de surface) étaient hypothétiques.

4. CHOIX DES METHODES DE RECONNAISSANCE

Des études géologiques de surface n'auraient apporté que peu d'éléments pour apprécier l'intérêt économique du contenu de la Cuvette congolaise, étant donné l'allure subhorizontale probable de la couverture sédimentaire.

L'exécution des forages d'exploration s'avérerait nécessaire dès le début mais il était évident que, pour des raisons économiques, il fallait en limiter le nombre et les situer à des endroits privilégiés grâce à une détermination préalable des structures profondes.

Les procédés géophysiques utilisés dans la recherche pétrolière paraissaient à priori être ceux qui devaient permettre de résoudre le problème, à savoir: choisir les endroits de forage, déterminer approximativement les profondeurs utiles à atteindre, rendre possible l'établissement de corrélations entre les données fournies par des sondages d'une part et les observations géologiques faites en périphérie du bassin d'autre part, au cours de plusieurs missions de terrain, aidées dans certaines régions qui s'y prêtaient, par des études photogéologiques.

Il était nécessaire cependant d'adapter les méthodes de la recherche pétrolière au cas particulier d'une reconnaissance géologique préliminaire à grande échelle.

Avec un minimum de dépenses, les études géophysiques devaient mettre en évidence les grandes unités structurales et en particulier localiser les zones d'épaississement de la couverture sédimentaire afin d'y placer les sondages pour recouper les séries stratigraphiques les plus complètes possible.

Les conditions particulières reprises ci-dessus ont déterminé le choix des méthodes géophysiques de reconnaissance.

a) Méthode magnétique

Les levés magnétiques aériens permettent d'obtenir une idée approchée de l'épaisseur d'un bassin sédimentaire si, à la base de celui-ci, existent des formations éruptives ou métamorphiques, en général fortement magnétiques par rapport aux terrains surincombants d'allure subhorizontale.

Pour être utiles, les levés magnétiques doivent être réalisés suivant des profils

très rapprochés. Etant données l'importance des surfaces à couvrir, l'absence quasi totale des photographies aériennes, la difficulté d'installer et de déplacer dans ces régions les équipements de repérages géographiques nécessaires, le coût d'une telle opération serait devenu prohibitif. On a cependant estimé nécessaire de mesurer au sol les variations de la composante du champ magnétique vertical suivant les itinéraires parcourus par les équipes de levés gravimétrique et altimétrique, le supplément de dépense étant dans ce cas très réduit.

b) Méthode gravimétrique

A la condition d'avoir des informations sur la répartition des densités dans l'ensemble sédimentaire proche de la surface, cette méthode permet d'y préciser des structures. Mais il est nécessaire en outre, de disposer d'un réseau dense de stations, car des anomalies dues aux hétérogénéités de la couverture peuvent passer inaperçues devant l'ampleur de certains déséquilibres isostatiques ou même devant des anomalies régionales. Il s'agit en fait par cette méthode de déterminer des structures de caractère local.

Un levé gravimétrique aussi détaillé n'aurait pas eu de justification: son coût aurait été trop élevé en raison des difficultés de pénétration et de l'insuffisance des données topographiques et altimétriques dans la Cuvette congolaise. On s'est limité à un levé à larges mailles, d'intérêt géodésique. La détermination des altitudes a été faite par des moyens barométriques. Quelques itinéraires ont été réalisés à pied et la presque totalité des routes accessibles en voiture ou en jeep ont fait l'objet de mesures gravimétriques, magnétiques et altimétriques. Près de 6.000 points de mesures ont été effectués, soit une moyenne de 100 points par degré carré.

c) Méthodes sismiques

Les méthodes sismiques par réfraction et réflexion ont été estimées les plus adéquates pour déterminer, même approximativement, l'épaisseur des formations de couverture relativement meubles reposant sur des sédiments anciens plus évolués. Les contrastes de vitesses entre ces milieux ont permis d'utiliser avec succès la méthode sismique-réfraction. En partant de la périphérie du bassin l'on a pu établir la correspondance entre la nature des sédiments et la vitesse de transmission des ondes sismiques, et suivre l'approfondissement de ces formations géologiques vers le centre de la Cuvette congolaise.

La méthode sismique-réflexion a été utilisée surtout sur rivière en appliquant la technique particulière du travail sur eau. Au stade de reconnaissance, ce procédé avait l'avantage d'être rapide, et facile aux points de vue des déplacements et des levés topographiques.

Outre les informations précieuses sur des séries stratifiées profondes, que la méthode sismique-réfraction n'avait pu atteindre, ces essais de sismique-réflexion ont été suffisants pour démontrer l'utilité de la méthode à un stade ultérieur de l'exploration, en fixant les modes opératoires efficaces à la détermination des structures profondes.

d) Sondages

Deux sondages entièrement carottés ont été effectués, le premier à Samba (profondeur: 2.040 m) à 80 km environ au nord-est de Boende, le second à Dekese (profondeur: 1.856 m) à 200 km au nord de Mweka (Kasai), en des endroits choisis ainsi qu'il a été dit plus haut, d'après les résultats de la méthode sismique-réfraction.

L'étude paléontologique et pétrographique des carottes a permis d'établir la corrélation stratigraphique entre les sédiments traversés et leurs homologues étudiés en surface, à la périphérie du bassin, par des missions géologiques.

5. COUTS ET DUREES DES TRAVAUX

De 1952 à fin 1956, les dépenses se sont réparties approximativement comme suit:

en millions de FB

Préparation des missions, étude et coordination des résultats	3,-
Missions géologiques 1952-53-54-55-56	4,-
Missions gravimétriques et magnétiques 1952-53-54-55 ..	6,-
Missions sismiques 1952-53-54-55-56	45,-
Sondage carotté de Samba 1954-55 (2.040 m)	41,-
Sondage carotté de Dekese 1955-56 (1.856 m)	29,-
Missions de surveillance et de contrôle 1953-54-55-56 .	1,-
Droits miniers et frais de gestion	1,-
Matériel acquis (valeur non amortie à fin 1955)	20,-

Les missions géologiques de surface ont été poursuivies après 1956, ainsi que les études en laboratoire et la mise au point des résultats scientifiques en vue de leur publication.

La brièveté de cette note ne permet de donner aucun résultat détaillé, aussi le lecteur que le problème intéresserait voudra-t-il bien se reporter aux publications citées ci-dessous, dans la bibliographie.

6. CONCLUSIONS

Dans le cas particulier de l'investigation de ce vaste bassin sédimentaire, le levé de sismique-réfraction, malgré son réseau très dispersé (117 sondages sismiques) a contribué pour la plus grande part aux conceptions actuelles sur la géologie de cette région.

Ces résultats ont été heureusement complétés par les données fournies par les autres disciplines géophysiques: sismique-réflexion, gravimétrie et magnétisme.

L'ensemble de ces données physiques a été extrapolé et combiné aux observations géologiques faites en surface et dans les sondages, pour donner une idée d'ensemble de la géologie du bassin, de sa couverture et des grandes unités structurales qui en constituent le substratum.

Cette première reconnaissance a permis, en peu d'années, d'écarter des régions sans intérêt minier, a circonscrit les zones vers lesquelles devraient porter les efforts de recherche futurs, et a fourni tous les éléments nécessaires à l'établissement de programmes et de budgets pour la poursuite du travail entamé dans la Cuvette congolaise.

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Les résultats scientifiques des missions du Syndicat pour l'étude géologique et minière de la Cuvette congolaise sont publiés dans:

"Annales du Musée Royal du Congo Belge, Tervueren, Belgique - Sciences géologiques - série in 8°",

et dans:

"Annales du Musée Royal de l'Afrique Centrale, Tervueren, Belgique - Sciences géologiques - série in 8°".

Quatorze volumes ont été publiés à ce jour. Ils portent les numéros: 14 - 19 - 21 - 26 - 27 - 28 - 29 - 31 - 33 - 34 - 35 - 36 - 37 - 39.



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FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.5.2.3

India

LIMITING FACTORS
IN THE MECHANIZATION OF MINES
UNDER CONDITIONS PREVAILING
IN LESS DEVELOPED AREAS

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

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A.5.2.3. LIMITING FACTORS IN THE MECHANIZATION OF
MINES UNDER CONDITIONS PREVAILING IN
LESS DEVELOPED AREAS.

by

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INDIA

Need for mechanisation

1. The majority of the underdeveloped countries of the world have launched programmes of planned economic development with the object of increasing the national income and the living standards of their peoples. Rapid advances in the standard of living and the production of consumer goods will be possible only after a solid foundation of heavy industry, transport and power resources is laid. These in turn are based on mineral raw materials such as coal, iron ore, oil, metallic ores etc. Thus the speed with which the development programmes can be implemented is intimately linked with the speed with which local mineral resources can be exploited. It is in this context that the need to mechanise mines has to be examined, since under certain favourable conditions mechanisation results in the speedy execution of mine development and exploitation programmes, often resulting in the saving of $1\frac{1}{2}$ to 2 years in the deferment period.
2. Mechanisation also results in higher rate of production and increase in output per manshift with a consequent increase in the earnings of the mine workers. The extent to which the output per manshift may be increased depends upon a variety of factors such as the level of industrialisation in the country, the availability of skilled personnel and mode of occurrence of the deposit.
3. A reduction in the unit cost of operation is also achieved by mechanisation, but only when a number of important conditions are fulfilled. The main advantages of mechanisation are concentration of operations with consequent reduction in supervision cost, higher output, high OMS and large production from limited areas. But these advantages accrue only when the equipment used is of the right type for the job, it is operated effectively at the rated capacity, is never allowed to unnecessarily idle either for shortage of power, spare parts or servicing and maintenance facilities. The need for effective coordination in the various phases of mining operations, ore handling and preparation cannot be over emphasised. Another important consideration is the matching of the various types of equipment to be used for the different jobs. Even if the right equipment is selected for each of the interlinked operations per se, a mechanisation programme may still fail for want of co-ordination between the various phases.
4. The capital expenditure in the development of large mechanised mines is very high. In India, it is of the order of Rs.50/- per ton of annual output in the case of coal mines, involving a capital outlay of Rs. 50 million for a mine

designed for an annual production of a million tons. If the machines work at their rated capacity, the expense on account of depreciation and interest charges at a rate of 15% will work to about 7.5 million rupees or Rs. 7.50 per ton. If for any reason the machinery works at only 50% of rated capacity the fixed charges will increase to Rs. 15 per ton, thus rendering the entire mechanisation scheme uneconomical. The National Coal Development Corporation in India have procured a 15 cu.yds. dragline for the opencast mine in Kurasia and will soon have four more, the largest of which has a bucket capacity of 39 cu. yds. and costs Rs.10.5 million. The substantial financial losses which may arise if they are not kept operating at their rated capacity is obvious.

5. Since electrical energy requirements are also large in mechanised mines and form an important item in the cost of production, the cost at which it will be available has also an important bearing on the likely unit mining cost.

6. Often, instead of total mechanisation, partial mechanisation of certain unduly labour wasteful operations may well result in a reduction in unit operating costs. Such schemes of partial mechanisation have been successfully implemented in Singareni Collieries in India. Similarly partial or complete mechanisation may prove successful in certain particularly well developed areas in a generally underdeveloped country, while elsewhere perhaps more labour intensive techniques may prove cheaper.

7. The development of industries like iron and steel, heavy machinery, electrical machinery etc. will create excessive internal demands for minerals in a finished or semi-finished state, necessitating mine mechanisation to meet increased demands. As minerals in a semi-finished or finished state acquire many times their value in the raw state, creation of mineral-based industries in a country will result in generating the additional wealth necessary to defray the cost needed for mine mechanisation.

8. As an alternative to mechanisation, the increasing requirements of minerals can be obtained by greatly increasing the number of workers employed. But the substitution of labour intensive techniques does not do away with the need for additional capital expenditure or operational costs, since progressive labour welfare legislations in various underdeveloped countries entail the spending of large amounts of money to discharge these obligations. One of the main reasons for mine mechanisation in underdeveloped countries like India has been this additional need for capital and operational expenditure even when labour intensive methods are employed. In India, whereas the value of mineral production in 1960 showed an increase of more than 25% compared to 1956, due to increased mechanisation, the increase in the number of workers was only 3.5%.

9. Since most of the mining operations are hazardous and require working under conditions of great hardship for the men employed, such as excessively high temperature, humidity, constrictions in working space, artificial light, inadequate ventilation, etc., substitution of machines for men in such hazardous occupations will be very desirable.

Mechanisation vis-a-vis Labour - Intensive Techniques

10. Although speedy industrialisation makes mine mechanisation desirable, the requirement for mechanisation in general and the nature of mining investment in particular impose certain limits on the practicability of increasing mineral production through mechanisation.

11. Mine mechanisation schemes require large capital investments not only for the mine, mill and smelter but often for the development of transport, handling and power facilities. A programme of iron ore development in India, for instance,

includes, among other items of capital expenditure, construction of about 320 Kilometres of broad gauge rail road, capable of handling 6-10 million tons of ore every year through a difficult hilly terrain. The order of capital required for mechanised iron ore mines in India is Rs. 50 to 60 per ton of annual finished product, excluding capital required for rail road, harbour and port facilities which may often far exceed the capital required for the development of the mine alone.

12. Another important point is that whereas in certain industries mechanisation results in improvement and standardisation of the quality of the product, mine mechanisation actually results in the lowering of the quality of the ore produced. Since mechanisation is not amenable to selective mining or picking, often barren masses within an orebody have to be mined along with the ore, necessitating the installation of beneficiation plants. As mechanisation results in concentrated large outputs, such beneficiation processes also need to be mechanised, thereby entailing additional capital for suitable beneficiation plants.

13. There is also a diminution in the size of the mine product obtained by mechanised mining. The intensive blasting, mechanical loading and crushing which are the features of mechanised mining result in excessive fragmentation of ore creating a number of new problems. In coal mines the production of dust greatly increases the risk of explosions, requiring additional expenditures on measures to suppress it. Finos of iron ore, and manganese ores require to be sintered, briquetted, agglomerated, or pelletised before they can be marketed, thereby requiring additional capital for such plants.

14. Further capital expenditure on mining investments are inflexible. No two mines possess identical conditions of mining. The mining equipment designed for an orebody of a certain type may not be suitable for efficient deployment in the mining of another ore-body. Similarly processing equipment suitable for ore from one mine may be unsuitable for ores from another.

15. On account of the particularly inflexible nature of mining investments, it is essential to ensure that the degree of risk is low in such investments. Yet mining investments generally involve a higher degree of risk than other industries. Uncertainties regarding shape, size, extent and tenor of ore bodies, unpredictable price fluctuations, possible technological advances which may render established plants obsolete, shifts in demands arising out of development of substitutes, changes in international politics and national policies all add considerably to the risks of mine investments. It is possible within limits to reduce such risks by well directed programmes of mineral exploration. But such work is costly and time consuming and increases the deferment period considerably. A desire on the part of mine investors for a higher rate of return on investments and quicker rate of return of the invested capital is thus quite understandable.

16. There are certain types of mineral deposits which on account of their shape, size or mineralogical distribution, are not suitable for mechanisation. A large number of mica mines in India fall into this category. This also is a case with small mines with very low production from small reserves.

17. A very vital factor in underdeveloped countries is the prevalence of high unemployment and under-employment. Increases in population aggravate the problem. In India it has been estimated that the unemployment figure at the beginning of the Third Plan period was 9 million. Even if the plan works out according to schedule and provides employment opportunities for an estimated 14 million, the backlog of unemployment at the beginning of the Fourth Plan would be 12 million. It is against this disquieting background that schemes of industrialisation have to be examined.

18. Direct employment opportunities in relation to the capital invested varies widely from industry to industry. The capital required per person employed is of

the order of Rs. 160,000 for steel, and Rs. 100,000 for a heavy machine building plant, while it is only Rs. 11,000 for newly opened mechanised coal mines and Rs. 20,000 for partially mechanised copper mines. Mechanised mining is thus comparatively labour intensive. At the same time, the labour employment potential of non-mechanised mines per unit of investment is very much higher. It is desirable to retain this characteristic of non-mechanised mines unless, of course, other overriding considerations favour mechanisation in special cases. Coal, oil and minerals capable of earning or saving foreign exchange can reasonably be included in this category. This in the long run may provide far greater employment opportunities by quickly building up a base for consumer goods industry.

19. Present trends in mine mechanisation favour development of large units of production as these are more economical than smaller units. As the basis of economy is the continuous deployment of equipment at their rated capacities, modern mechanised mines entail large concentrated outputs. Obviously, such schemes will not succeed if the transport facilities are inadequate.

20. Mechanisation makes great demands on power. The availability of adequate power and the rate at which it can be made available at the mine are, therefore, important factors in the feasibility and success of mechanised programmes of development. For instance, a diesel power station installed exclusively to meet the requirements of a mine, the cost of electric power at an estimated requirement of 30 units per ton of ore produced may be as high as Rs. 7.50 per ton. When the mines are located within economic transmitting distance of a public utility Co. supplying electricity, the corresponding power expenses may be only Rs. 1.50. It may thus be advisable to mechanise the mining operations in relatively well developed areas of an underdeveloped country, while in the remoter areas, the factor of power alone may render manual mining operations more economical than mechanisation.

21. Mining like any other industrial project requires considerable number of technical and skilled personnel during the various stages of planning, design, erection, maintenance and operations. Thus in a mining project, a large number of engineering and technological personnel of various categories, of considerable experience and competence are required in the planning stage in order to prepare a project report, study in detail its economics, technical aspects and its erection there-after. Whereas their services in any mining scheme are required only at the project stage, personnel in charge of operation and maintenance will be responsible for the continued efficient operation of the plant throughout the life of the mine. While the number of skilled personnel required for operation is generally higher than that required for maintenance, the degree of skill required for operation is lower and can be acquired in a shorter period. Skill and knowledge of maintenance, however, are more difficult to acquire and take more time. Since the number of such men needed for an individual project is small it is easier to arrange for necessary training facilities for this purpose. It may be advisable to associate 10 to 15% of the future requirements of the key personnel for maintenance at the erection stage itself. The policy of entrusting erection to a certain group and allowing the taking over of the plant by an entirely new group of maintenance and operational men is not good for obvious reasons. As in all underdeveloped countries the know-how of modern equipment is very meagre it is very desirable to attach a large number of local engineering personnel of various categories with foreign consultants who can train them for various jobs during planning and construction period.

22. The type of personnel selected for such training is also important. While the persons selected should have adequate and sound technical background and training it is advisable to choose comparatively young men so that the benefit of their training can be made available to the country for a long period. Almost all the underdeveloped countries would welcome the assistance of foreign experts for training their local personnel. Unfortunately while requesting for such assistance the underdeveloped countries are not specific for the requirements with the result that

in many cases such opportunities are not fully utilised and a foreign expert visits a number of places or institutions in the country and offers suggestions of a general nature which are not of much help either in the training of personnel or in the development of natural resources.

Conditions Prevailing in Under-developed Countries

23. All under-developed countries are faced with the problem of inadequate capital and a very low rate of capital growth. Resources of private capital are small, obliging governments to take on increasing burdens of investments ranging from 30% to 60% of the total outlay in various countries.

24. Foreign exchange required for the purchase of plant and machinery, spare parts and payment to foreign consultants and foreign nationals employed in the design, execution and operation of various projects is often very large. For instance, the foreign exchange requirements of India in the Third Plan mineral development schemes alone is Rs. 288 crores out of total investment of Rs. 766 crores. The foreign exchange resources of under developed countries are very low and they have to largely depend on foreign aids to implement their development plans and programmes. The best means of raising foreign exchange in under-developed countries is by launching upon determined export drives for indigenous products, restriction on domestic consumption of export earning commodities, increasing the profitability of exports by maintaining a competitive price for export products and high productivity. This means that capital should be made available for industries which have good export potential.

25. Expenditure on foreign exchange required for employment of foreign nationals can be reduced by introducing well thought out training programmes. Expenditure for machinery, plant and stock can be reduced, provided the available natural resources, permit, the development of machine manufacturing industries in the country. The foreign exchange required during the development stage has necessarily to be obtained by external assistance and by creating a favourable atmosphere for the in-flow of private foreign capital.

26. One of the greatest obstacles to the speedy development of mine mechanisation is the non-availability of mining machinery. The total requirements of mining machinery for the Third Five Year Plan of India amount to more than 410 millions of rupees, the bulk of which has to be imported from abroad, since manufacturing capacity within the country is either lacking or inadequate.

27. Rapid development of mineral resources demand the services of a great number of qualified technical personnel competent in various branches of science, engineering and technology. But gross inadequacy of trained personnel is a feature in most of the under-developed countries of the world. There is almost complete absence of men capable of performing the duties of planning and designing for the various stages of operation pertaining to the exploitation of mineral deposits. The short fall in the requirement of such trained personnel as of necessity involves the calling of technicians from the industrially advanced countries of the world thereby imposing a considerable strain on the foreign exchange position of most of the under-developed countries of the world.

28. It has already been emphasised that a detailed knowledge of an orebody is essential before the heavy capital investments of mine mechanisation can be incurred. Unfortunately, the state of knowledge regarding the mineral resources in under-developed countries is wholly inadequate. It is necessary that the national resources of minerals should be ascertained to decide if it is desirable to allow export of any mineral product in large quantities in order to acquire foreign exchange and specific prospects will have to be explored in detail for the production of the magnitude considered admissible. The problem thus is to make a rapid appraisal of

the local mineral resources and to take up detailed exploration of attractive mineral prospects to bring about production quickly.

29. Though the importance of mineral exports as a source of foreign exchange is well realised, exploitation of such resources is inadequately done mainly because of the lack of adequate knowledge of the resources of the under-developed countries. This generally tends to favour conservation of minerals by withholding production for export as much as possible, because of the fear that export of such minerals may result in the impoverishment of the under-developed country. A rational use of national mineral resources may however call for the export of mineral raw materials to the industrially advanced nations requiring such minerals in exchange for the much needed machinery, plant and foreign exchange.

30. Scope for Mechanisation of Mines in Under-developed Countries

30. Though the characteristics and requirements for successful mine mechanisation and the unfavourable conditions prevalent in under-developed countries militate against mechanisation, yet it is justified under certain conditions.

31. Only mineral deposits containing large reserves are capable of sustaining high rate of production. If the shape, size and extent of orebodies are such that large tonnages have to be produced from a limited space, it would be advantageous to mechanise mining operations. For example, a deposit with a width of 100 ft. and an exposed outcrop running over 10,000 ft. may contain the same amount of reserves as another one whose dimensions may be of the order of a 1000 ft. by a 1000 ft. In the former case, it is possible to produce the required tonnage with a limited degree of mechanisation, while in the later it will require to be completely mechanised to obtain that output.

32. In cases, where there is a need to quickly raise large tonnages of ore, mining schemes may be mechanised provided the overall profitability is substantial. Fuel minerals like coal which are essential for development of any industry and minerals which will generate foreign exchange because of their export value or their ability to act as substitutes for essential imports would come under this category.

33. A large mining project requires about 4 to 5 years for bringing it to full production; if the period of preliminary exploration is included it may be as long as 7 to 10 years. Often certain types of ore deposits can be fully assessed only after extensive underground exploratory programmes. It is often possible to speed up underground exploratory operations by substantial mechanisation using suitably designed equipment available in the market. If the mine required the erection of a mill and smelter, then it is good practice to ensure that the production from the mine starts about 6-months before the mill can function and attains peak production at about the same time that the mill and smelter are ready for working. If it is estimated that the period for development and stope preparation by semi-mechanisation required for full production exceeds the time required for the erection and operation of the mill and smelter then there is a strong case for mechanisation of the whole of the development operations. Development of mines where the erection of mill or smelter are not required should be completely mechanised as this will undoubtedly bring the mine to the level of production atleast 1 to 2 years earlier, depending on the volume of work required. In India such cases may arise in the development of coal, Iron ore and Manganese ore mines required to be developed for purposes of exports of these ores.

34. In every mine there are certain phases of mining operations which are unduly wasteful of labour and impose considerable hardship and fatigue on the men employed. Such phases are dewatering, blast hole drilling, ore hoisting and long distance manual transport. These operations should invariably be mechanised in all cases. There is a great scope of mechanisation of such operations in underdeveloped countries.

Trend in Mine Mechanisation in India.

35. There has been a great increase in the quantity and variety of mineral production in India in recent years. Rapid strides have been made in India in extensive and intensive programmes of mineral exploration and as a result the knowledge of mineral resources of the country is now more clear and precise than before. In actual mining operations, there has been a shift from the traditional method of manually operated mines to the development of large mechanised units. The entire production of coal in the public sector is to be obtained from a small number of intensively mechanised mines with large individual outputs. The number of coal mines with an annual production of 300 thousand tons was only six in 1946. Compared to this, the National Coal Development Corporation of India alone has plans for the development of seven coal mines each capable of producing about a million tons of coal every year. The total production of iron ore in 1946 was 974,000 tons. At present atleast 4 large iron ore mines have plans for an annual production of 2 million tons each every year, equivalent to a daily production of 10,000 tons of R.O.M. ore. These have reached various stages of development. In the development of coal mines referred to above, the Civil Engineering work taken up during the Second Plan Period amounted to Rs. 10.19 crores, equivalent to 30% of the total amount estimated for the projects. Power shovels with capacities of 2½ cubic yard to 8 cubic yard with 5 to 6 dumpers for each shovel are being used. In the Kursia open cast coal mines, it is proposed to employ a drag line of 15 cubic yard capacity. Four more drag lines, the largest of which has a bucket capacity of 39 cubic yards (cost 10.5 million rupees) have been ordered for the open cast mines at Birsampur in Madhya Pradesh and South Balasore in Orissa.

36. The lignite operations at Palana envisages the removal of 69 metres of overburden by large capacity bucket excavators to expose lignite bed of about 3 to 6 metres thick. Another important mechanised mine under development is at Nellore, at Madras, which envisages the utilisation of large capacity bucket excavators for the mining of lignite. Iron ore mines being developed by the Public Sector, have plans, for large production through mechanisation. The Mines at Rajhara, Kiriburu and Barsua, each with a target production of 2 million tons of sized ore annually have reached various stages of development. In the Private Sector, the Gua Iron ore mines have been fully mechanised from the face to loading point for an annual production of 2 million tons. Similar mechanization programmes have been introduced in the Noamundi iron ore mine of Tata Iron & Steel Co. and the Bolani iron ore mines of Bird & Co. The number of coal cutting machines has increased from 359 in 1949 to 696 in 1960, similarly the aggregate H.P. of electrical plant used in mining increased from 160,000 in 1949 to 500,000 in 1960. After coming into production of the Heavy Mining Machinery Plant at Durgapur and the Heavy Electrical Plant at Bhopal (now under construction) and the successful implementation of the various programmes of training now being launched by the Government, mine mechanisation is likely to extend to a large number of other mines in the country.

Programmes and Measures for the Implementation of Planned Mine Mechanisation

37. The manufacture of mining machinery is obviously an important requirement for the successful implementation of mine mechanisation programmes. The main advantage of local manufacture of such machinery is that the drain on foreign exchange will be greatly reduced also removing the necessity for maintaining large stocks of spare parts.

38. The Government of India has set up a Heavy Engineering Corporation for the manufacture of equipment required for steel making, heavy machine tools and such machines as coal cutters, loaders, conveyers, mine locomotives etc. The total capacity expenditure is of the order of about 180 crores for a scheduled annual

production target of 260 thousand tons of such machinery. The Heavy Machinery Plant at Ranchi in Bihar, after its target of production of 80 thousand tons in a year is reached, is expected to cope with the demands for the bulk of the equipment required for adding to the country's steel making capacity at the rate of one million tons per year. The production of 45 thousand tons of mining machinery will also substantially meet with the heavy machinery requirements of the coal mining industry. Similarly after programmes of manufacture of heavy electrical equipment such as heavy duty generators, motors, transformers etc., are achieved, the country is expected to be largely self-sufficient in these items.

39. The importance of providing training facilities has already been emphasised. At the beginning of the Second Plan, there were only two institutions in India imparting instruction in Mining Engineering of a degree standard. The capacity of these institutions has since been greatly increased and additional courses for mining engineering have been started in six other colleges and technological institutions. The State Governments are establishing fourteen institutions for the training of subordinate personnel required in the mining industry. It is expected that these steps will ensure that the bulk of the additional personnel requirements of the mining industry, estimated at sixteen hundred engineering graduates and four thousand diploma holders, will be met.

40. The purpose of mechanising mines is defeated if there are transport bottlenecks, power shortages. Therefore the development of power and transport and mine mechanisation programmes should move hand in hand. The objectives in this regard should be, to encourage regional development and also different modes of transport rail, road and water. In India the concentration of coal production in Bengal and Bihar coal fields has posed serious problems in transport and power shortage. A solution of these problems is being attempted through simultaneous action in the development of out-lying coal fields, transporting coal by road and also by water ways.

41. Under-developed countries may simultaneously consider the establishment of metallurgical industry, Electrical Engineering Industry and Chemical and other allied industries. This will increase the indigenous consumption of minerals and metals thereby greatly strengthening the domestic mining industry. Another profitable step will be the installations of a few custom mills and smelters which may often enable a large number of small deposits in a mineral district to be economically exploited.

42. Since any programme of mechanised mineral development calls for an expenditure of substantial amount of capital, with a high foreign exchange component, a favourable atmosphere has to be created for the flow of such capital. The factors which have an important bearing on the formation of both domestic and foreign capital are mining mineral laws of the country the taxation policy of the local government, the political stability of the country and its policy on nationalisation, facilities for repatriation of income and investment and laws pertaining to the formation and operation of companies etc. They must all be liberalised to attract foreign capital and technicians.

43. In India in order to encourage the formation and investment of capital for various industrial development schemes, the Government have introduced a number of incentive schemes such as exemption from income-tax during the initial years of a company's activities, liberalisation of depreciation allowance rate, development rebates on new plants and machinery, provision for exemption from income tax of foreign technicians locally employed etc. Steps have also been taken to ensure guaranteed repatriation of foreign capital and avoidance of double taxation, and the most recent one is the formation of a joint company - Manganese Ore India Ltd. in which 49% holdings are of a British Company and 51% of the Central and State Governments.

44. All the under-developed countries have a long tradition of Labour intensive techniques in working mines. Mine mechanization is a new experiment which is likely to present several obstacles, which must be surmounted before these countries are anywhere near the achievement of their goal of industrialisation, raising the standard of living of their people by removing poverty, ignorance and disease and resulting in the creation of a new society in which importance of human values and individuality will be respected.



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MINING LEGISLATION
IN UNDERDEVELOPED COUNTRIES

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MINING LEGISLATION IN UNDERDEVELOPED COUNTRIES

By

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1. In this paper a general description is given of the most usual provisions of the mining legislation in force in some of the countries of the British Commonwealth. It is hoped that the experience gained whilst these countries were being developed and their laws were being evolved might prove of value to other countries considering legislation connected with the development of the mineral resources of areas where conditions may be similar.

Public Ownership of Minerals

2. Underdeveloped countries are usually unable to provide the funds needed for developing their mineral resources and they must therefore seek to attract outside capital. One of the factors that can discourage a mining concern wishing to invest money in prospecting, however, is the fear that when a workable deposit has been found it may be necessary to negotiate with a number of smallholders, any one of whom, in consequence of his unwillingness to agree reasonable terms, or even because he cannot be found, may jeopardise the project after considerable sums of money have been spent. Many countries of the Commonwealth have overcome this by passing laws vesting the minerals in the Crown (the equivalent of the State) which then grants the rights to prospect and mine. Any proceeds from fees, rents or royalties are then paid into general revenue for the benefit of the country as a whole.

3. In Jamaica, for example, under the law which vested the minerals in the Crown in 1947, the owners of the land are compensated by the payment of 5 per cent. of the royalties. However, no payment may be made after the fiftieth anniversary of the commencement of the law and the twenty-fifth anniversary of the day upon which the minerals were first won. In some of the provinces of Canada, where before the introduction of mining legislation the minerals passed to the owners with the surface rights, the vesting law provides for the State only to retain the mineral rights in land alienated after it came into force.

Administration

4. In the countries of the Commonwealth, the granting of the more important titles such as exclusive prospecting licences and mining leases was originally vested in the Governor on behalf of the Crown or the State. In those countries which are approaching or have gained independence this power is now exercised by the Minister for Mines.

5. In other territories, notably in Fiji and the British Solomon Islands, this power is vested in a Mining Board, the members of which are appointed by the Governor. In Southern Rhodesia, a Mining Affairs Board acts mainly in an advisory capacity to the Governor in regard to applications for prospecting and

mining titles, for which purpose it may summon applicants and owners of land to give evidence on oath and to produce books, plans and accounts. Among other matters, these Boards consider and approve programmes submitted by the holders of prospecting titles.

6. In addition, there is provision in the law for the appointment of the officers of the Mines Department, the head of which may be a Secretary for Mines, a Commissioner of Mines or a Chief Inspector of Mines. In countries where there is a great deal of mining activity and a large Mines Department all three may be appointed in the above order of responsibility. There is also provision for the appointment of officers to administer mining activities in the field such as Mining Commissioners, Inspectors of Mines and Wardens. In Southern Rhodesia, a Mining Commissioner is placed in charge of Mines Department matters in each district. Inspectors of Mines are generally qualified mining engineers whose duty it is to inspect mines for safety and deal with matters of a technical nature, whereas Wardens are generally employed on duties which do not call for considerable technical knowledge.

The Meaning of the Word "Mine"

7. There are many definitions of a mine in the laws of the countries of the Commonwealth, but in general the word covers all workings where minerals are removed from the ground. For the purpose of this definition minerals usually include all mineral substances except such materials as clay, stone, gravel or sand used in their natural state and mineral oils and gas, which are usually dealt with under different laws. The type of excavation or the method of obtaining the minerals, whether from surface or underground workings, seldom affects the interpretation of the word.

Prospecting

8. The names given to the documents which convey the right to explore and prospect for minerals differ from country to country in the Commonwealth and the rights which they convey vary, but they may be divided into two general classes:

- (a) Those which convey a non-exclusive right to prospect - usually known as "prospecting rights" but may be called "prospecting licences" or "prospecting permits".
- (b) Those which convey an exclusive right to explore and prospect for minerals over an area specified in the document - known as "exclusive prospecting licences", "exclusive rights to explore", "exclusive prospecting orders" or, in some countries, "prospecting licences".

Prospecting may also be done under titles which convey the right to exploit and mine minerals.

9. Prospecting rights do not convey any exclusive right to search and the holders have no protection from the attentions of other prospecting right holders until they have appropriated prior rights to the minerals by planting protection notices, pegging claims or applying for some other form of mining title. Before a person can obtain a right, he must show that he has control of sufficient funds to cover any compensation he may become liable to pay to those who suffer damage as a result of his activities. In addition he may be required to make a deposit, provide a banker's guarantee or enter into a bond

with acceptable sureties to cover this liability. Normally, the power is reserved for the issuing official to refuse a right to anyone to whom there is objection because of previous breaches of the mining law, with, of course, the right for an aggrieved applicant to appeal to a higher authority.

10. A prospecting right permits the holder to make excavations, build camps on unoccupied land, take water from lakes and rivers and cut such timber as he needs, provided it is not privately owned or protected by the State. These privileges are, however, subject to control and the prospector cannot divert any water from its normal course without permission or prospect on any private or reserved land without legally notifying the occupier or the responsible authority.

11. Exclusive prospecting licence. In nearly all the countries of the Commonwealth the rule of priority prevails. This means that the first person who demarcates an area in accordance with the mining law or applies to the proper authority in the correct form, has the prior right to the area. This has the disadvantage that it may discourage the investment of capital in systematic prospecting, since, before embarking on the considerable expenditure that this entails, a prospector or company would require protection from "claim jumpers" and speculators. In order to accommodate suitable persons who would be willing to invest capital in an exploration and prospecting campaign that could be disorganised by these attentions, provision is therefore usually made for the issue of exclusive rights to explore and prospect over an area for a particular mineral or group of minerals, and this is usually called an "exclusive prospecting licence". There are in general two varieties of this licence: one which covers a comparatively small area, usually not exceeding 16 sq. miles (41 sq. kilometres) and which contains conditions which are laid down in the law; and another, the "special exclusive prospecting licence", which is generally issued for a larger area for a particular period and under special conditions which must be negotiated and approved by the Government in each case.

12. An exclusive licence conveys the same rights as a prospecting right, the prescribed rent being usually about £5 per sq. mile (2.59 sq. kilometres) and seldom more than £10 per sq. mile. It is generally issued for a period of one year, renewable for further periods of one year each up to a limit, which is usually 5 to 7 years. Provided he has conformed with the conditions of his licence, the holder has the right to mining title over any part of the area where he has discovered the minerals of value for which he has the right to search, or, in countries where there is provision in the mining law for mining claims, he may peg claims. The conditions of an exclusive prospecting licence include the obligation to carry on bona fide prospecting operations to the satisfaction of the Government. Most laws provide that the holders of exclusive prospecting licences shall keep full and accurate records of their operations and, at prescribed intervals, submit returns and reports of the work done together with the results.

13. Applicants for a special exclusive prospecting licence are usually called upon to submit a programme of work and to guarantee a required minimum expenditure on exploring and prospecting the area, which must be approved by the Government before the licence is granted.

14. Overlapping exclusive prospecting licences. In many Commonwealth countries the law provides that the area covered by an exclusive prospecting licence shall be closed to all prospecting by others, even though they may not be concerned with the mineral for which the exclusive prospecting licence is issued. However, a trial has been made, with some success, of the issue of

special exclusive prospecting licences which provide that the holders of prospecting rights may enter to prospect for other minerals and which reserve to the State the right to issue exclusive prospecting licences to prospect for other minerals over the same area.

15. Such a special licence was found useful, for example, when an application was received for a very large area, the closing of which to others would have curtailed development of the mineral reserves, especially as it was known that prospectors were active when the application was made. Care had to be taken, however, not to issue overlapping licences for those minerals which would probably occur in such a manner as to lead to interference by one prospector with another. Nevertheless, some mining companies dislike taking up areas into which others may gain entry and, under the guise of prospecting for other minerals, obtain information regarding their activities that could be of value to competitors or speculators.

16. Protection notices. To enable the small prospector to gain protection during his search for minerals, the laws of some countries enable the holder of a prospecting right to post a protection notice which gives him the exclusive right to prospect and peg claims for one month over an area of a given radius from the notice. In Kenya, for example, the radius is 500 yards (457 metres) and in Northern Rhodesia 1,000 yards (914 metres). The prospecting right holder who first plants a protection notice has the prior right to prospect the area that it covers.

Mining Title

17. There are two main kinds of mining title:

- (a) Claims, locations and mining rights which are of short term and have to be renewed annually.
- (b) Mining leases, concessions and grants which subsist for from five to ninety-nine years and may be renewed for one, or sometimes more, similar periods.

Claims and locations, which generally consist of blocks of ten contiguous claims pegged at the same time, may be located by the holder of a prospecting right or exclusive prospecting licence. In some countries it is necessary also to have found valuable minerals in the course of prospecting under the right and to have posted a discovery peg at the point where they were found before a claim may be pegged.

18. Short term mining titles. Claims are rectangular areas which in some countries may be acquired by the holders of prospecting rights by pegging, the first holder who pegs a claim having the prior right to that claim. The sizes and shapes of claims differ considerably in each country, but in general claims for precious stones and precious metals are small while base metal and base mineral claims are large; the size also varies in accordance with the remoteness of the area and the sparseness of its population. For instance, a precious metals alluvial claim in Tanganyika is 300 feet (91 metres) long by 100 feet (30.5 metres) wide and has an area of nearly 0.69 acres (0.28 hectares), whereas a claim for minerals other than diamonds in Bechuanaland, a large part of which is occupied by the Kalahari desert, may be as large as 300 morgan (about 260 hectares). Claims must be registered at the nearest Government Mines Department office within a specified period that varies according to the

remoteness of the area in which the claim is pegged, but is usually one month.

19. In some countries claims are not provided for in the mining law, but mining rights or river locations may be issued for working small alluvial deposits; other types of ore bodies are covered by the issue of mining leases. Normally, mining rights and river locations are only granted when there is reason to believe that the mineral-bearing qualities of the land are not such as to justify an application for a mining lease. A mining right or river location is granted for a stream and the land lying within a specified distance of its centre, varying from 100 feet (30.5 metres) to 200 yards (183 metres). The length of a mining right or river location along the centre of the stream varies from 800 feet (244 metres) in Sierra Leone to 1,800 yards (1,645 metres) in Swaziland.

20. Long term mining titles. Mining leases and concessions are issued for larger areas and for periods of from five to ninety-nine years in those cases where considerable capital is necessary to develop the mine and where the applicant needs security of tenure over a longer period for his operations to be economic. The area of a mining lease differs from country to country, but is generally larger than that of a claim, location or mining right. For example, in Fiji the area of a precious stones lease may not be more than 10 acres (4 hectares) whereas in the Brunei Mining Enactment, although the size of a mining lease is not specified, the maximum area a lessee may hold is as much as 5 sq. miles (13 sq. kilometres).

21. Under a mining lease the holder may make the excavations necessary to extract the mineral from the ground and erect the buildings and machinery needed for this purpose. In most countries the lease also conveys the right to erect machinery and buildings for processing the mineral for sale, to stack or dump mineral or waste, to impound or divert water, lay pipes, make water-courses and to construct roads and tramways on its area. In Southern Rhodesia, however, the siting of these works is under the control of the Mines Department official in charge of the district, to whom a plan showing their situation must be sent. The Mines and Minerals Act of Southern Rhodesia also allows the holder of a mining title to peg sites for residences and the above works outside his area with the permission of this official.

22. Mining leases carry certain obligations, the breach of which may lead to the lease being forfeited if the lessee does not rectify the breach before the expiry of a notice calling upon him to do so. In addition to the requirement to comply with the provisions of the mining law, these obligations include the payment of both surface and mineral rents. Surface rent goes to the owner or occupier of the area covered by the mining works and buildings. It is assessed by the Government, after consulting the owner, at the estimated annual value of the land when used for the purpose for which it was being employed at the time it was first occupied by the mining lessee. This surface rent is often subject to periodic revision.

23. Mineral rent is an annual payment to the Government for the right to remove the minerals from the ground. It varies considerably from country to country and for the different minerals and types of mineral deposits for which the lease has been granted. In Sierra Leone, the rent for leases for minerals in lode formation is 10 shillings per acre and for precious metals in alluvial leases 5 shillings per acre. In a few countries mineral rent is treated as a minimum royalty or "dead rent", the amount of which may be deducted from royalty payments. Lessees are also obliged to pay compensation to the surface

holder for damage or removal of buildings, economic trees, crops or the surface of the land.

24. A mining lessee must commence operations within a given period, generally six months, and must continue working during the tenure of the lease, unless prevented from doing so by unavoidable accident. In British Honduras and Fiji a minimum labour force must be employed during the year and in Kenya and Southern Rhodesia a minimum amount of development work must be done. Proper records of production, sales, staff and labour employed must be kept. In addition, correct plans and sections showing all workings and the known extent of the mineral deposits, their assay and sample values, must be available at the mine and a record must be kept of all abandoned underground workings.

25. The lessee is also obliged to keep the Government informed by the periodic submission of returns and reports, the nature and contents of which are laid down in the mining law.

Demarcation of Prospecting and Mining Areas

26. In the mining laws of the Commonwealth countries there is always provision for the description, demarcation and, when necessary, the survey of prospecting and mining areas, which must be fixed with sufficient accuracy and permanence, but without incurring more expense than can be justified for each class of title.

27. Exclusive prospecting licence. Before applying for this licence an applicant has to make a preliminary demarcation by erecting temporary beacons at the four corners of the area. These often consist of a pile of stones with direction trenches, but in some countries where the vegetation is heavy the applicant has to clear the bush on the boundary lines. After the application has been approved by the Government, permanent concrete corner beacons must usually be erected and the boundary lines surveyed by a qualified surveyor who must fix by theodolite and steel tape the position of these beacons by connecting them to the national survey grid or to some well known point. When there is little possibility of dispute with others as to the position of the boundaries, permission may be given for the survey to be dispensed with; but if an application is made for a contiguous area, the holder may be called upon to share the expense of surveying the common boundary.

28. Special exclusive prospecting licence. The same rules regarding demarcation and survey are applicable to the special licence, but in cases where the area concerned is extensive, it may be described by reference to natural boundaries such as the banks of rivers and streams or by political boundaries, provided their situation is not in dispute and they are well known.

29. Claims. The pegging of a claim is done by erecting pegs and notices at each of the four corners. The pegs are stout wooden posts inserted firmly in the ground with notice boards attached. In wooded country they may consist of notice boards nailed to trees and where the undergrowth is heavy the boundary lines are marked by clearing a path from corner to corner of the claim. Usually one and sometimes all four notice boards must have legibly written on them at least the name of the prospector who pegged the claim, the number of his prospecting right and the date on which he did the pegging. After the claim has been registered or licensed, the registration or licence number is added to the information on the notice boards. Claims are normally not surveyed but in Southern Rhodesia a claim holder may, by special registration, arrange for his location to be marked with permanent corner beacons of solid

masonry and for a survey to be made by a qualified surveyor. The plan or diagram is then registered at the Mines Department office.

30. Mining rights and river locations. Before the holder of a prospecting right can apply for a mining right or river location he must erect temporary beacons at the highest and lowest points on the river or stream of the area required and prepare a plan using approximate magnetic bearings. After approval, the area must be surveyed, usually by chain and compass, and demarcated by means of beacons erected above flood level at the upper and lower boundaries.

31. Mining leases. The preliminary demarcation and the requirements for the erection of permanent beacons and precise survey by a qualified surveyor are the same as for an exclusive prospecting licence, except that permission cannot be given for the survey to be dispensed with.

Control of Possession, Purchase and Sale of Certain Minerals

32. The necessity for the control of possession, purchase and sale of a particular mineral depends on the value of the mineral that can be carried and hidden on the person and the ease with which it can be illicitly mined, sold and smuggled. In Nigeria, for example, the following minerals are controlled: the ores of tin, columbium, tantalum, tungsten and zinc; radioactive minerals; uncut diamond, and any other mineral which the Government may decide to declare. In countries where precious metals such as gold and silver are found, possession of these and their ores is controlled.

33. When possession of a mineral is controlled, it becomes illegal for anyone to possess it unless he is the holder of a prospecting or mining title or right, the holder of a licence to trade in the mineral, or the authorised agent or employee of one of those persons and he has obtained possession of the mineral in a legal manner. Also, no one may sell the mineral unless he is satisfied that the purchaser is the holder of a licence to trade in it, and no such holder may purchase the mineral unless he is satisfied that the vendor is legally in possession of it.

34. The holder of a licence to trade in any mineral is obliged to keep proper records showing his purchases and sales, the dates when these were made, the persons with whom the transactions took place and the stocks of mineral he held after each transaction. Officials of the Mines Department are usually given the power to inspect these books and the licensee's stocks of mineral at any time. The export of the mineral is often controlled by limiting those who may do so to recognised banks or to the holders of licences to export, who must pass all such minerals through the customs control before they are exported from the country. There are severe penalties for illegally possessing, purchasing, selling or exporting controlled minerals.

Principal Royalty Systems

35. A royalty is a form of compensation paid to the owner of the minerals, whether a private individual or the State, for the exhaustion of an asset and is ideally priced at a figure at least equal to the "value of the mineral" as it lies in the ground, i.e., the value of the mineral recovered, less a reasonable charge for extraction, treatment and transport to the point of sale.

36. There are three main systems in use in the British Commonwealth for calculating royalties and taxes to be paid on minerals, each being employed under different circumstances.

- (a) A profits tax or a levy based on the "profitability" of the mine. This is appropriate when reliable accounts are kept and the value of the mineral concerned can be established with reasonable accuracy.
- (b) A percentage or a sliding scale based on the value of the production or sales from the mine. This method is applicable when the work of preparing and checking the statement called for by the previous system cannot be justified by the amount of revenue that would result. It is most appropriate for assessing royalties to be paid by small prospectors and miners who cannot employ staff capable of preparing elaborate accounts.
- (c) A fixed sum per ton or other unit for each mineral or metal raised or sold. Originally most royalties were of this type, but this system is now usually limited to those cases in which the product is sold in small lots at varying prices or is difficult to value accurately because it is employed in an integrated industry, such as brickmaking or pottery manufacture in which both the mine (or quarry) and the factory are run as a single business unit.

Application of Royalty Systems

37. Profits tax. The most usual form of levy based on "profitability" is a profit or income tax. An example of this is the 50/50 tax which is now often included in petroleum producing agreements and leases, whereby the Government, as the royalty owner, takes 50 per cent. of the profits from the production of petroleum. This system has been adopted in Ghana and Nigeria.

38. Another form of mineral tax based on profitability is that which is calculated on a sliding scale dependent on the "yield ratio", which is the ratio that the yield (i.e., the value of the mineral won less the actual operating costs) bears to the recovery (i.e., the value of the mineral won). Although not strictly a royalty, the best example of this is found in Ghana, where the following duty is charged on all minerals, except on diamond won by individuals and on outputs of gold less than 50 ounces (1,555 grams) per annum won by individuals:

<u>Yield ratio</u>	<u>Rate of duty chargeable on the value of the minerals won</u>
15% or less	NIL
More than 15% but less than 30%	0.02% for every 0.1% by which the yield ratio exceeds 15%
More than 30% but less than 70%	3% plus 0.04% for every 0.1% by which the yield ratio exceeds 30%
70% and over	19% plus 0.02% for every 0.1% by which the yield ratio exceeds 70%

39. Percentage of mineral value. The most usual form of royalty or mineral tax is based on a percentage of the value or on a sliding scale according to the value of the mineral concerned. For example, in Nigeria a sliding scale system is adopted for tin ore, royalty being payable on the tonnage of metallic tin contained, which is assumed to be 72.5 per cent. in weight of the ore exported. The royalty is calculated as the sum of the following:

				<u>Royalty</u>
Of that part of the price per ton				
which does not exceed £250				2%
which exceeds £250 but not £350				4%
" " £350 " " £450				10%
" " £450 " " £550				20%
" " £550 " " £900				30%
" " £900 " " £1,100				33%
" " £1,100 " " £1,300				35%
" " £1,300				40%

The price of tin is taken as the average of the mean of spot and forward prices in London for the calendar month immediately preceding export.

40. Fixed sum. A royalty based on a fixed amount per ton or other unit of material is seldom employed for the ores of metals, but is usually adopted in the case of building stone, clay, sand or similar materials. The following are examples from Tanganyika:

Gypsum	Shs. 2 per ton
Magnesite	Shs. 3 per ton
Clay	50 cents per 100 cubic feet
Stone	Shs. 1 per 100 cubic feet

Miscellaneous Matters

41. In addition to those already mentioned, a number of other matters are dealt with in the Mining Laws of the various Commonwealth countries, among which is the procedure for reporting and inquiring into accidents and the measures that must be taken to prevent their occurrence. All Inspectors of Mines and senior officers of the administration are given the right of entry upon any mines in their districts and may order any matter which they consider dangerous to be rectified, subject to the right of the holder of the mining or prospecting area or his agent to appeal to a higher authority, provided that meanwhile work is stopped in the place affected if the officer deems it advisable. Safety regulations may also be made by the Executive Council.

42. In some countries the Chief Inspector of Mines may order reasonable measures to be taken to prevent soil erosion or to restore the land by filling holes and replacing soil after prospecting and mining operations. There is also a clause providing penalties for "salting" and for making false statements regarding the holding of mining or prospecting title in order to induce persons to invest capital. Provision is sometimes made for the settling of disputes, either by the Inspector of Mines or Warden on the spot, or by arbitration.

43. All Government officers are prohibited from acquiring rights to prospect or mine in the country in which they are employed.



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**CONFÉRENCE DES NATIONS UNIES
SUR L'APPLICATION DE LA SCIENCE ET DE LA TECHNIQUE
DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES**

Point de l'ordre du jour : A.3.3.1

Sénégal

PROSPECTION HYDROGEOLOGIQUE
POUR L'ALIMENTATION EN EAU
DE DAKAR

Par R. DEGALLIER

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

NOTES

1. Les mémoires choisis pour être présentés en séance générale pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

2. Les mémoires choisis pour être présentés en séance spéciale pourront être obtenus à la Conférence dans l'une seulement de ces langues officielles.

3. Les résumés qui ont été rédigés pour tous les mémoires par les auteurs de ceux-ci pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

4. Préablement à la Conférence, les mémoires et les résumés ne feront pas l'objet d'une distribution générale mais d'un tirage restreint destiné aux délégations des gouvernements et autres participants officiels. La publication et la distribution générale des actes de la Conférence s'effectueront conformément aux règles et pratiques agréées par le Comité des publications des Nations Unies.

PROSPECTION HYDROGEOLOGIQUE POUR L'ALIMENTATION EN EAU DE DAKAR

par R. DEGALLIER

1. INTRODUCTION

1. La ville de Dakar est actuellement alimentée par trois centres de captages fournissant 60.000 m³/j à plus de 350.000 habitants. Mais on prévoit déjà que ce débit deviendra rapidement insuffisant pour couvrir les besoins d'une ville en pleine expansion, et de nouvelles recherches sont en cours.

2. Nous donnerons tout d'abord un aperçu des caractéristiques de chacun de ces centres de captages existants, et nous essaierons de montrer en même temps quelle a été chaque fois la contribution des différentes méthodes scientifiques de recherche à leur découverte et à leur installation.

3. On verra que l'application de ces méthodes a toujours été en s'intensifiant, non seulement parce qu'elles étaient progressivement mises au point, ni à cause des exigences de plus en plus importantes entraînées par le développement, mais surtout parce que les réserves les plus immédiatement disponibles une fois consommées, il fallait rechercher des ressources de moins en moins accessibles, qui demandent des investissements dont la rentabilité doit être assurée par des justifications de mieux en mieux fondées..

4. Nous exposerons ensuite quelles sont les recherches en cours, et ce qu'on peut attendre de l'application des différentes spécialités de l'hydrogéologie.

5. En conclusion, nous dirons quelques mots de l'organisation de la recherche grâce à laquelle les opérations citées ont pu être conduites dans d'excellentes conditions.

2. NAPPE INFRA-BASALTIQUE

6. La nappe contenue dans les sables quaternaires qui recouvrent toute la presqu'île du Cap Vert d'un manteau continu de dunes, se trouve couverte, dans la tête de la presqu'île, par des coulées de basalte.

7. Cette nappe fut mise en exploitation d'une façon extrêmement progressive, puisque l'exécution de quelques 50 puits et forages de reconnaissance et d'exploitation s'échelonne de 1925 à nos jours. Grâce à ces travaux, on connaît la topographie et la nature de son mur (marnes crétacées et éocènes), et l'on a pu distinguer différentes coulées dans les basaltes qui la recouvrent (ARNAUD 1952, GORODISKY 1954).

8. Les seules études dont on ait profité dans ces aménagements furent les recherches hydrologiques très approfondies d'HUBERT (1922), basées sur l'étude des fluctuations de la nappe de 1912 à 1922, qui lui permirent d'énoncer que "dans les dunes de la presqu'île du Cap Vert, la quantité d'eau de précipitation pénétrant en profondeur au cours de l'année est égale à la hauteur d'eau tombée moins 25 cm environ".

9. La connaissance de ce bilan, jointe à la progressivité de l'aménagement expliquent probablement que le nombre de puits abandonnés par suite d'intrusion d'eau salée soit faible, bien qu'aucune étude géophysique n'ait encore précisé les limites de la nappe douce avec l'océan, et qu'aucun piézomètre ne renseigne sur les mouvements éventuels du front salé.

10. Le débit actuellement exploité est de 16.000 m³/j, mais on s'attend à être obligé à le réduire, notamment à cause d'une diminution de l'alimentation imputable à l'urbanisation d'une grande partie du bassin versant, englobé maintenant dans la banlieue de Dakar.

3. TIAROYE

11. Dans les mêmes formations sableuses quaternaires, à 12 km de Dakar au delà des épanchements basaltiques, le centre de Tiaroye fut mis en exploitation de façon moins empirique. Une étude géophysique compréhensive par sondages électriques de toute la presqu'île du Cap Vert de Dakar à Cayar précisa en 1946 l'épaisseur des sables à eau douce et leurs limites au contact des eaux salées et des marnes éocènes, et repéra les zones où les sables aquifères paraissaient les moins argileux. Avec plus de 50 m d'épaisseur des sables mouillés sur plus de 10 km², la région de Tiaroye était la plus favorable (BREUSSE 1952).

12. De difficiles problèmes techniques se posèrent lors de la mise en exploitation, et se posent encore, en raison de la finesse des sables, de moins de 0,3 mm de diamètre, et de l'agressivité des eaux. C'est pourquoi de nombreux forages d'étude et de reconnaissance furent exécutés, pour mettre au point les précautions à prendre dans l'élaboration des massifs filtrants.

13. Durant les premières années d'exploitation (1952 - 1957), la nappe fut surexploitée, et l'on en tira jusqu'à 20.000 m³/j sans tenir compte de l'alimentation annuelle ; on enregistra effectivement une avancée du front salé, mais on savait que la nappe de Sebikotane pourrait bientôt prendre le relai. Actuellement on pense qu'avec 10.000 m³/j, un équilibre pourra être maintenu entre les années à pluies déficitaires et celles à pluies excédentaires, sans mouvement sensible du front salé.

4. SEBIKOTANE

14. On se préoccupait depuis longtemps déjà de trouver 40.000 m³/j supplémentaires. Trois solutions ont été envisagées :

15. Celle d'exploiter la nappe des sables quaternaires au-delà de Tiaroye là où son épaisseur était inférieure à une vingtaine de mètres, aurait exigé 50 à 100 forages dispersés sur une centaine de kilomètres, ce qui rivalisait difficilement avec l'extrême simplicité de l'opération Sebikotane, où un seul forage de 50 m de profondeur pouvait suffire à fournir tout le débit.

16. La seconde solution présentait le plus de garantie à l'époque. En effet, la nappe maestrichtienne était bien connue par les forages de l'intérieur du Sénégal, et, grâce au levé de la carte géologique, les formations sableuses maestrichtiennes avaient été identifiées à Pout, à 50 km de Dakar. (TESSIER 1946).

17. Une première campagne géophysique, effectuée en 1946, en précisa l'extension vers l'Ouest à faible profondeur jusqu'à un accident tectonique, la "faille de Sebikotane"; au delà duquel ils étaient surmontés par un horizon électriquement beaucoup plus résistant, lui même recouvert de marnes éocènes. Il s'agissait de calcaires Paléocènes fissurés, et un sondage en révéla en 1947 les excellentes qualités hydrauliques. Plus à l'Ouest encore, au delà d'un second accident tectonique les me-

sures géophysiques montrèrent en profondeur l'existence d'une épaisse série essentiellement argileuse ou à eau saumâtre.

18. Un forage d'essai d'exploitation fut alors effectué à Pout, et le maestrichtien grésocalcaire et sablo argileux se révéla difficile à carter. On redhercha ensuite l'extension de ces faciès par une campagne de 6 forages totalisant plus de 2.500 m. Mais ces forages semblèrent montrer des faciès plus argileux, peut-être à la suite d'un échantillonnage défectueux, et l'on s'orienta résolument vers une troisième solution, que les calcaires paléocènes découverts cinq ans auparavant faisait envisager.

19. Alors qu'à Dakar et à Tiaroye, à cause du recouvrement éolien, la structure des gisements ne pouvait être décelée par l'observation hydrogéologique directe à Sébikotane les affleurements, bien que peu nombreux permettaient d'emblée de se faire une idée de la complexité de la structure géologique, dont on devait attendre beaucoup d'anomalies dans le comportement des eaux souterraines.

20. C'est pourquoi des études hydrogéologiques, géophysiques, les recherches par forages, les mesures hydrologiques et météorologiques ont alterné en de multiples campagnes dont nous allons retracer le déroulement en ne citant que l'essentiel des apports de chacune d'elles, car deux publications ont déjà exposé ailleurs, l'une (DEGALLIER, MARCHAND 1955) la structure et l'évolution géologique de la région, le comportement des différentes nappes en présence et leurs réactions entre les pluies et les fluctuations de la nappe, et les perturbations apportées par deux années d'exploitation à gros débit.

21. Le levé de la carte géologique avait fait apparaître sur le flanc Ouest du dôme anticlinal de N'Dias, où le maestrichtien affleure sur plus de 300 km², un contact anormal avec les marnes éocènes surmontant les calcaires de Sébikotane, indiquant la présence d'une faille ou d'une série de failles en escaliers. Un premier inventaire des points d'eau montrait un écoulement de la nappe phréatique divergeant autour de ce massif anticlinal.

22. Une seconde campagne géophysique (1951) reconnut par sondages électriques l'extension et la structure des calcaires paléocènes, ainsi que leurs relations avec la mer. Ces calcaires, entre 20 et 100 m de profondeur, s'amincissent pour disparaître vers le Nord, touchent à l'Est des roches sablo-argileuses du maestrichtien à travers la faille de Sébikotane, à l'Ouest les marnes éocènes à travers une autre faille, et plongent au Sud sous l'océan où ils deviennent salés.

23. Un inventaire détaillé des points d'eau, avec nivellement de précision (BENSE 1952) mit en évidence leur alimentation à travers la faille de Sébikotane dans les formations maestrichtiennes, et leur exutoire plus à l'aval dans ces mêmes formations.

24. En 1953, une trentaine de forages de reconnaissance prospectèrent ce gisement aquifère. Grâce aux carottages électriques qui furent faits systématiquement des corrélations étroites purent être faites malgré la présence des failles, malgré une érosionant-éocène très capricieuse du sommet des calcaires, et malgré l'existence d'une vallée quaternaire fossile. Les découvertes faites lors de cette campagne de forages obligèrent à une troisième étude géophysique pour compléter les précédentes.

25. Ensuite pendant deux années consécutives (1954-55) de très importants essais de pompages furent conduits quant aux débits qu'on envisageait d'exploiter, pour se rendre compte des réserves, du mode de renouvellement de la nappe, et surtout des risques de contamination par la mer.

26. L'exploitation démarra fin 1958 lorsqu'une conduite de 800 mm de diamètre eut été posée jusqu'à Dakar.

27. La plupart des forages de reconnaissance avaient été aménagés en piézomètres, et observés périodiquement depuis 1953. Un pluviomètre permit d'avoir une idée de la hauteur annuelle des précipitations. Dès 1960, le besoin se fit sentir d'avoir une mesure plus précise de l'alimentation de la nappe, et une dizaine de pluviomètres et deux pluviographes furent installés. En même temps, l'étude des fluctuations du niveau de la nappe phréatique fut entreprise par des mesures mensuelles dans tous les vuits de la région, afin de distinguer si possible l'effet des pluies de celui des exploitations, et de tenter de délimiter ainsi par des mesures directes, l'extension du cône de pompage.

Enfin, des mesures hydrologiques ont été entreprises pendant les saisons de pluie de 1961 et 1962, en vue de mesurer les quantités d'eau de surface qui pourraient être utilisées à sursupplier la nappe dans la zone critique du bord de mer.

29. Parallèlement à ces nombreuses études à objectif hydraulique étaient effectuées, par des compagnies privées, des recherches de pétrole-gravimétrie, magnétique, sismique, forages profonds - dont il était tenu compte simultanément.

30. Tous les faits nouveaux étaient intégrés au fur et à mesure aux connaissances antérieures, mais il est apparu que chaque fois que des réinterprétations d'ensemble étaient effectuées, de nombreuses hypothèses nouvelles étaient fécondées par la confrontation inédite d'autres éléments. On est donc encore loin d'avoir extrait tout ce qu'on peut de la masse des observations, à laquelle s'ajoutent régulièrement de nouvelles saisons de mesures de fluctuations du niveau des eaux souterraines.

31. Ces mesures périodiques de niveau sont un des plus puissants moyens d'investigation de l'hydraulique souterraine, et en même temps l'un des plus économiques lorsqu'elles sont faites sur des points d'eau existants.

5. NAPPE MAESTRICHTIENNE

32. Actuellement, les besoins en eau de Dakar dépassent de nouveau les disponibilités, et un nouveau cycle de travaux d'études est en cours pour mettre au jour des ressources nouvelles. Alors qu'il y a 15 ans les ressources envisagées se trouvaient à moins de 50 km de Dakar, il faut actuellement dépasser ce chiffre. Pourtant, des ressources abondantes et inexploitées existent encore dans les sables de la presqu'île, mais nous avons vu qu'elles se prêtent mal à une exploitation centralisée, et on préfère les réserver à l'agriculture.

33. On se propose donc soit de prélever dans le lac de Guières les eaux de crue du fleuve Sénégal, et de les amener à Dakar par une conduite de plus de 200 m de longueur, soit de capter la nappe maestrichtienne captive à une centaine de km de Dakar, soit encore ce, qui serait le plus économique, de l'exploiter sur le flanc Est du massif de N'Dias, par l'intermédiaire des calcaires paléocènes, comme à Sebikotane. On n'exclut pas non plus de déminéraliser l'eau de mer à un prix de revient compétitif. Ces 4 études sont actuellement menées parallèlement par des organismes spécialisés.

34. Déjà en 1954, une étude hydrogéologique de la nappe maestrichtienne avait été réalisée (DEGALLIER 1954) d'après l'étude des quelques 60 forages existants dans l'intérieur du Sénégal. Une stratigraphie détaillée avait été établie et l'évolution paléogéographique du bassin sédimentaire sénégalais précisée. Une étude hydrochimique avait incité à émettre certaines hypothèses sur l'alimentation vraisemblablement très faible de cette nappe.

35. Mais rien n'était connu de la dynamique de la nappe, et on ne pouvait faire aucune prévision des répercussions qu'entraînerait une exploitation intensive par exemple à 50.000 m³/jour. C'était là l'objectif des études hydrauliques souterraines effectuées en 1961 - 1962 sur les forages existants (AUDIBERT 1962). L'ordre de grandeur de la transmissivité a pu être évaluée, mais des mesures plus précises exigent des travaux complémentaires onéreux : pose de piézomètres, mesure de l'âge absolu de l'eau, essai par traceur radio-actif, etc..

36. L'exploitation de cette nappe artésienne pour l'alimentation en eau de Dakar est possible partout, mais la zone la plus intéressante se trouve non loin à l'est de Sebikotane sur le flanc Est de l'affleurement anticlinal maestrichtien de N'Dias, où elle bénéficie comme à Sebikotane d'une alimentation directe ; en évitant ainsi d'utiliser des réserves de décompression, on limite au maximum les risques d'intrusion d'eau salée.

37. Les études en cours dans ce secteur en sont à leur phase initiale comprenant essentiellement de la photogéologie et de la cartographie géologique au 1/20.000. Là aussi en escaliers compliquent la disposition des calcaires paléocènes, dans lesquels on recherche les zones de meilleure fissuration et ayant la meilleure action de drain vis-à-vis des sables maestrichtiens.

38. Une quatrième étude géophysique a permis de lever l'hypothèse qui pesait sur ce secteur du fait de la présence d'eau sursalée dans le lac Tanma, exutoire évapora-

toire entraînant la partie Nord... En fait, l'épaisseur des formations salées est faible - une centaine de mètres -, et il s'agit surtout de formations argileuses peu aptes à rapidement.

6. CONCLUSIONS

39. L'originalité des méthodes qui viennent d'être énumérées réside surtout dans l'utilisation coordonnée pendant maintenant plus de 15 ans de toute une gamme de méthodes classiques de prospection hydrogéologique.

40. L'ordre dans lequel ces méthodes doivent être appliquées n'est pas indifférent. Les reconnaissances géologiques et l'inventaire des points d'eau préparent les prospections géophysiques ; puis les forages, phases la plus onéreuse, font le contrôle concret des résultats des méthodes inductives, et l'on peut ensuite passer à l'exploitation. Nous avons vu à combien de reprises ce cycle d'opérations avait été réitéré, amenant chaque fois une réinterprétation fructueuse des faits précédemment acquis, grâce à l'intégration mutuelle de données de discipline voisine.

41. Pour des opérations importantes, la mise en oeuvre de ces méthodes n'est plus de la compétence d'individus isolés, mais d'équipes bien rodées de spécialistes confirmés dans des disciplines variées. L'intervention de telles équipes peut être conçue comme se limitant à l'opération en cours, au risque de mécomptes causés par une connaissance insuffisante du pays. Mais l'efficacité en est décuplée par une permanence des mêmes personnes dans plusieurs opérations successives. Pour être utilisé à temps plein, de tels spécialistes doivent avoir une compétence géographique étendue, ce qui exclu qu'ils fasse partie d'administrations locales et rend au contraire souhaitable qu'ils appartiennent à des organismes de recherche privés ou publics.

42. Lors de l'étude de la région de Sebikotane, tous les travaux étaient décidés par les responsables locaux des Travaux Publics, en liaison constante avec les spécialistes du service Fédéral de l'Hydraulique de l'Afrique Occidentale, les hydrogéologues de la Direction des Mines, les Compagnies de Prospection Géophysique et les Entreprises de Forages. Pendant les phases actives des travaux, des réunions hebdomadaires permettaient à chacun d'avoir une vue d'ensemble de tous les problèmes et de ne pas s'égarer dans sa spécialité propre. L'équipe ainsi en action il y a 10 ans dans le cadre de l'ancien Gouvernement Fédéral est pratiquement encore en place aujourd'hui. La responsabilité des travaux d'hydraulique continue à incomber aux services locaux du Gouvernement du Sénégal, qui font appel contractuellement lorsqu'ils en sentent le besoin aux services d'organismes français de recherche, dont certains ont hérité du personnel des anciennes Directions Fédérales,

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